GOVERMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH

Flood Plan Coordination Organization

FAP-25
FLOOD MODELLING AND MANAGEMENT

COORDINATION ADVISORY TEAM
FOURTH MISSION REPORT
APRIL 1993

Governments of
Denmark, France,
The Netherlands and
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Coordination Advisory Team

Fourth Mission Report

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APPENDICES

LIST OF ABBREVIATIONS

AFPM	Active Flood Plain Management
BIWTA	Bangladesh Inland Water Transport Authority
BLE	Brahmaputra Left Embankment
BWDB	Bangladesh Water Development Board (under MIWDFC)
CAT	Coordination Advisory Team
CE	Chief Engineer
CTA	Chief Technical Adviser
Danida	Danish International Development Assistance
DEM	Digital Elevation Model
DHI	Danish Hydraulic Institute
EC	European Commission
EIA	Environmental Impact Assessment
FAP	Flood Action Plan
FAPMCC	FAP Model Coordination Committee
FFM	Flood Forecasting Module
FHS	Flood Hydrology Study
FMM	Flood Management Model
FPCO	Flood Plan Coordination Organization
GIS	Geographic Information System
GM	General Model
GOB	Government of Bangladesh
HME	Hydraulic Modelling Engineer
HYMOS	Software Package for Hydrological Data Processing
MC	Model Coordinator (previous Resident Model Coordinator)
MIKE 11	Software Package for 1-D River Modelling
MIKE 21	Software Package for 2-D Estuary and Coastal Areas Modelling
MIWDFC	Ministry of Irrigation, Water Development and Flood Control
MPO	Master Plan Organisation (now WARPO)
NAM	Rainfall-runoff Model (Danish abbreviation)
NCRM	North Central Regional Model
NCRS	North Central Regional Study
NERM	North East Regional Model
NWRM	North West Regional Model
PDM	Planning Design Module
PoE	Panel of Experts
RMM	River Modelling Module
RRI	River Research Institute
SAR	Synthetic Aperture Radar
SCRM	South Central Regional Model
SERM	South East Regional Model
SOB	Survey of Bangladesh
SOM	Structures Operation Module
SWAM	South West Area Model
SWMC	Surface Water Modelling Centre
SWRM	South West Regional Model
SWSMP	Surface Water Simulation Modelling Programme
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 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 Organization (FPCO) with the Danish Ministry of Foreign Affairs (Danida) as the lead donor. The donor agencies of France, the Netherlands and the United Kingdom also contribute to the project.

The project has been ongoing since October 1990 with the coordination and the Flood Hydrology Study as the two major activities. The FHS is now completed. The Flood Management Model component started in mid October 1992 and will run in parallel with the continued coordination activities for the next two years.

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. The third mission took place in December 1991 and produced a report dated March 1992. During this mission it was decided that the present fourth mission of the team should take place in September 1992. Due to the late start of the FMM component the mission has been delayed until December 1992. In addition to these missions, one member of the Team of Short Term Experts has visited Bangladesh on two occasions to overview and guide the implementation of the Flood Hydrology Study.

The overall objectives of the CAT, as stated in the detailed Terms of Reference of 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 Fourth CAT 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)

As it was the case during the previous mission, the Model Coordinator (MC) of the CAT, Mr. Jørn Rasmussen, and the Hydraulic Modelling Engineer (HME), Mr. Emaduddin Ahmad, worked closely with the Team of Short Term Experts.

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 1992 and presented their conclusions and recommendations to FPCO on 9 December 1992.

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.

This report contains the views of the CAT which do not necessarily correspond to the views of the Government of Bangladesh or the four donors. Hence, all proposals presented in the report are subject to approval by the Government of Bangladesh and the donor countries.

1.2 Comments to the Draft Report

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

2. CONCLUSIONS AND RECOMMENDATIONS

The general conclusions and recommendations of the Fourth CAT Mission are summarised in the following sections. Unless otherwise specified, the recommendations made are directed at FPCO.

2.1 Key Issues

Morphology Study

The CAT considers morphological and hydrological change the single most critical environmental risk associated with the FAP. A number of specific morphological studies are undertaken as part of the FAP, but none of these address the overall morphological impact of proposed FAP interventions.

It is strongly *recommended* that the previously proposed mission of internationally renowned morphology experts to review available morphological information and draw up Terms of Reference for a nation-wide Morphology Study be fielded with minimum delay. This mission would in itself constitute a *preliminary morphological study* to be followed up by a more comprehensive study, identified by the mission, within the proposed Inter-Regional Study.

It is *recommended* that the World Bank be requested to field this mission. The mission should be fielded during the first half of 1993 in order to enable it to contribute to the planned morphology seminar of FAP 24 in August 1993.

Inter-Regional Study

As emphasized in the two previous CAT Reports, an Inter-regional Study is required to provide a considered overview of the combined effects of the regional proposals, and hence the overall environmental effects of the FAP. At the Local Consultation Group meetings in March 1992 in connection with the Second Conference of the Flood Action Plan, several donors expressed the need for such a study, to see the overall effects of the plan, and to enable proper prioritisation of investments.

The essential immediate component of this study would be the proposed Morphological Study, in close interaction with associated hydrological studies.

The CAT *recommends* that the Inter-regional Study be formulated as an extension of FAP 25, and that the four donors of this component (Denmark, France, The Netherlands and U.K.) be approached for support.

The Future of SWMC

The CAT is concerned about the implications of a possible GOB decision to relocate the SWMC to Faridpur as part of its institutionalisation under River Research Institute. Unless adequate SWMC modelling competence and capacity is retained in Dhaka, the sustainability of the modelling achievements of the FAP is threatened, and future work on detailed feasibility studies will suffer.

The CAT *recommends* to MIWDFC that a section of the SWMC be retained in Dhaka.

Data-base Harmonisation

During the last CAT Mission it was recommended that data base and processing software and formats within the FAP, as well as within the water sector in general, be harmonized. An Inter-Agency Committee on Data Improvement has made recommendations to this effect, but these have not been followed up.

The CAT *recommends* to the MIWDFC that the recommendations of this Inter-Agency Committee be translated into decisions and actions at minimum delay. The CAT stresses the importance of introducing compatible and flexible formats and softwares to allow easy exchange of data and information and easy introduction of and adaption to any new software that may become available at later stages.

2.2 Other Issues

Provision of Data

* In addition to the regular BWDB programme, there is a need to undertake field measurements at a limited number of stations during the 1993 monsoon season to support continuity in the modelling effort at the SWMC. The CAT *recommends* that the SWMC requests Danida (as was the case in 1991 and 1992) to support such minor programme.

* The issue of payment for data has still not been finally resolved. The CAT *recommends* that the proposal by the FAP 25 Model Coordinator to procure data through FPCO be adopted.

* An extensive morphological field measurement programme has been initiated in FAP 24. The CAT is concerned about the sustainability of this programme after the departure of the consultants, and *recommends* that GOB (through the BWDB) takes steps to ensure a lasting effect of this important programme.

Modelling Technology

* The CAT notes with satisfaction that modelling technology as such is becoming a minor issue. The SWMC/DHI is generally responding well to suggested software improvements.

* Description of hydraulic structures in MIKE 11 is an increasing problem for most FAP studies. The CAT *recommends* that SWMC requests DHI (free of charge) to improve the modelling software in this respect.

* It is now recognized by SWMC and several regional studies that morphological modelling on a regional scale is an unrealistic undertaking at the present stage. The CAT agrees that morphological modelling with MIKE 11 generally will be limited to analysis of sub-regional/local problems.

* Several FAPs find that the definitive information on model schematization and location of model cross sections is difficult to obtain from the SWMC. The CAT urges the SWMC to take necessary action to improve this situation.

Coordination within the FAP

* The completion and delivery of models from the SWMC is suffering delays in the order of 3-5 months. However, the CAT notes that these delays do not affect the FAP modelling progress significantly at this stage.

* The FAPMCC and the PoE have expressed concern regarding updating procedures for and accuracies of models in the FAP. The CAT has reviewed the notes prepared for the 5th FAPMCC meeting regarding these issues (by SWMC and FAP 25), and is in general agreement with the proposals contained in these notes. Hence a rolling updating procedure for the SWMC models appears appropriate (subject to scrutiny of data supply mechanisms), as do the proposed accuracy requirements for planning, feasibility and design.

* The CAT notes that the regional study consultants generally have responded very well to the recommendations of the FAP 25 Flood Hydrology Study to estimate design water levels on the basis of long term (25 years) simulations.

* FAP 3 is likely to continue with feasibility studies of strengthening of existing embankments and establishment of new ones along the left bank of Jamuna (FAP 3.2 and FAP 3.3). These studies, as indeed FAP 1, consider potential morphological and hydrological changes in the Jamuna, but would benefit from the more comprehensive analysis provided by the morphological component of the Inter-regional Study (Morphology Study)

* FAP 5 has expressed concern about the possible implications for the Gumti feasibility study of developments in the North-east (FAP 6 proposals), as

well as of possible embankment schemes along the Jamuma and Meghna rivers, in terms of water level changes in the Meghna. This lends additional weight to the *recommendation* of the CAT to initiate the Inter-regional Study as soon as possible.

* FAP 6 has expressed some reservation with respect to the accuracy of the pilot stage of the NERM and its ability to predict absolute water levels with a sufficient degree of confidence. The full model stage will only be available in April, 1993 too late to be used by FAP 6. It is the impression of the CAT that a satisfactory solution to this problem may be achieved through a closer collaboration between FAP 6 and the SWMC on modelling, similar to the extensive cooperation the two parties have had on field surveys. The CAT understands that since the time of the mission it has been agreed between the SWMC and FAP 6, through a cooperative effort, to develop and "Intermediate Model" (between the pilot and the full model stage) for simulations under FAP 6. The CAT *recommends* that FAP 6 takes required action in this respect.

* The CAT notes that the EIA Guidelines produced by FAP 16 underestimate the importance of morphological change as a key environmental determinant in Bangladesh. It is *recommended* that FPCO and FAP 16 address this limitation in the further work, including the preparation of final EIA Manuals.

Flood Hydrology Study

* As part of the final stage of the Flood Hydrology Study a number of potential FAP development scenarios have been investigated through long term simulations with the General Model (FHS Report Annex 2). The CAT finds that these simulations have provided useful insight into the possible range of water level changes in the entire river system in response to various FAP interventions (a first step towards the proposed Inter-regional Study). The CAT *recommends* that the FHS Annex 2 be made available to the regional studies before initiation of feasibility studies.

* During the last CAT Mission FPCO was requested to take a decision regarding safety margins for peak water levels. This has not yet happened. The CAT *recommends* that the proposed decision be taken soon, before the regional FAPs enter into the feasibility study phases.

Flood Management Model

* The CAT has provided guidance to the newly recruited FMM-team of FAP 25 in the concepts and planning of the FMM. Particular emphasis has been given to defining (and containing) the FMM activities vis-a-vis development of the NCRM at the SWMC, internal MIKE 11 development by DHI, and

application of the FMM results (the Planning and Design Module) to economic, social and other analyses by concerned users.

* The CAT stresses the importance of close interaction between the FMM and FAP 3, FAP 10(incl. BWDB), FAP 19 and FAP 20, as well as the SWMC.

* The CAT welcomes the planned FMM Workshop to be held in February 1993. One of the CAT members will participate during this workshop.

Future CAT Missions

* In addition to its coordination functions, the main tasks of the CAT in the future will be to guide the FMM development, and assist in addressing the overall morphological and hydrological consequences of the FAP.

* It is *recommended* that the future CAT Missions be planned to coincide with draft reports of the FMM, *as well as* with visits of the PoE to Dhaka. In accordance with the present FMM schedule the following CAT Missions are envisaged:

  - October 1993
  - April 1994
  - November 1994

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 (SWSMP), including rainfall runoff, hydrodynamic, sediment transport and salinity modules 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-I) were i) to develop the local capability in surface water simulation modelling, including a sustainable institutional set-up within a permanent Master Plan Organisation (MPO), now the Water Resources Planning Organisation (WARPO), and ii) to develop a structured approach to modelling with a General Model covering the whole country.

The Surface Water Modelling Centre (SWMC) under WARPO is implementing the programme with technical assistance from the Danish Hydraulic Institute (DHI), and with financial support from Danida.

The first phase of the programme finished at the end of 1988. The ongoing second phase (SWSMP-II) with a duration of four years will finish by November 1993. The GOB has requested support for a third phase, which is presently being considered by Danida.

4. KEY ISSUES

4.1 Issues for the Fourth CAT Mission

As has been the case for the previous CAT Missions, the Fourth CAT Mission has followed up on the general progress on the FAP modelling activities, the constraints and problems faced, and the coordination between the various FAP components, the SWMC and the involved GOB authorities. The findings and recommendations in this respect are reported in Chapters 5, 6, 7 and 10 below.

Furthermore, during the present mission the CAT has finalized its review of the FHS with particular emphasis to the review of Stage 3 of the study (Chapter 8), and to discussion with the project team of the Flood Management Model which started its activities in November 1992 (Chapter 9).

During the Third CAT Mission (December 1991) a number of issues were raised and recommendations given. The CAT is concerned to note that little progress has been made on several of these important matters, and consequently such issues have been raised again - this time as matters of increased concern and importance. The most important of these issues include:

- the proposed mission of internationally renowned experts to identify and make recommendations for an overall Morphological Study of the FAP

- the proposed Inter-regional Study to investigate the combined effects of the individual components of the FAP
  (This was raised already during the Second CAT Mission in May 1991)

- the proposed harmonisation of data-base and processing software and formats

Additionally, the question of institutionalization of the SWMC, and hence the sustainability of the modelling activities under the FAP (including the FMM), has been raised as a key issue.

4.2 Overall Environmental Effects of the FAP: River Morphology and the Inter-regional Study

Environmental issues are being addressed in the FAP, including FAP 16, in the environmental study components of the Regional Studies, and inherently in a number of the Supporting Studies. However, it appears to the CAT that a crucial environmental question facing the FAP, namely the overall effects of proposed and potential interventions on the environment, still need to be addressed.

The CAT raised the question of the "missing component" of the FAP during the second Mission (May 1991). The Third CAT Mission proposed a River Morphology Study as a key component of the (missing) Inter-regional Study (Chapters 9.2

and 9.3 of the Third CAT Report, December 1991). The discussion of these proposals shall not be repeated here. It is still valid.

The Morphology Study

It is the opinion of the CAT that the key to addressing this question lies in the analysis of the overall morphological effects of FAP interventions. Interventions in the riverine environment, such as the proposed embankment schemes along the Jamuna, may affect erosion and sedimentation processes and river planform developments with possible wide-ranging effects in the entire river and delta system. Natural phenomena such as sea level rise may also affect the morphology of the delta region within a relatively short period of time. These effects (e.g. changes in water levels in the main rivers) may in turn affect ecosystems and human activities such as fisheries and agriculture. They may also affect existing flood protection works.

A number of FAP-activities address morphological issues, notably the Regional Studies, FAP 1, FAP 9B, FAP 21/22 and FAP 24. Additional work on river morphology of direct relevance to the FAP has been carried out by the China-Bangladesh Joint Expert Team on Flood Control and River Training on the Brahmaputra, by the Jamuna Bridge Study, and at the SWMC. The CAT has reviewed the present status of these activities and discussed with the relevant consultants. It still appears to the CAT that all of these activities address specific and geographically limited problems, and that none of the ongoing projects as presently planned have capacities to address river morphology on a nation-wide scale, including major regional rivers, and including analyses of long-term morphological changes.

The CAT also notes that time is becoming a critical factor. The potential morphological effects of proposed interventions (given within the possible range of accuracy), and the associated consequences in terms of possible water level changes in the main rivers, should be known to the regional consultants before detailed feasibility studies are finalized.

Hence the CAT urges the GOB to field the previously proposed Mission of internationally renowned morphology experts at minimum delay. This Mission would review the available morphological information and studies, and prepare Terms of Reference for the required nation-wide Morphological Study. The Mission would also provide guidance to the regional consultants and the ongoing FAP projects with morphological components with respect to methodologies and coordination between the various studies. Hence the proposed Mission would constitute a *preliminary morphological study* to be followed up by the more comprehensive study identified by the Mission within the proposed Inter-regional Study.

It is proposed that the Mission (i.e. preliminary morphological study) be fielded during the first half of 1993 so as to enable the team to contribute to the planned seminar on morphology arranged as part of FAP 24 in August 1993.

Proposed draft Terms of Reference for the Morphology Mission are provided in Appendix 5. The CAT *recommends* that the World Bank be requested to field this Mission.

The Inter-regional Study

The CAT considers the Morphology Study as a key component of the proposed Inter-regional Study, the objective of which is to provide a considered overview of the combined effects of the regional proposals, and hence the overall environmental effects of the FAP.

The immediate function of the Inter-regional Study would be to analyse the overall morphological and hydrological effects of proposals emerging from the regional studies, initially in terms of likely changes in water level characteristics in the main river system. This information would be provided to the individual regional studies, in which the physical, environmental, economic and social consequences of such changes would be analysed. The consequences thus derived would in turn be communicated back, through the Inter-regional Study, to the relevant FAP components

Certain overall environmental consequences of the proposed FAP which would not otherwise be investigated (such as likely environmental effects in the delta) may have to be given initial consideration in the Inter-regional Study itself. This may include overall effects on the FAP of sea-level rise.

The analyses in Annex 2 of the Flood Hydrology Study of FAP 25, in which overall hydraulic effects of various development scenarios are investigated in a (fixed bed) General Model, represent a first step towards initiating an Inter-regional Study. With this study as the point of departure, and with the concern of FAP 25 and the CAT on overall morphological issues, the proposed Inter-regional Study (with the Morphology Study as an integral part) could logically be visualised as an extension of FAP 25.

Considering furthermore that FAP 25 is supported by four donor countries with interest in and concern for the FAP (Denmark, France, the Netherlands and U.K.), the CAT *recommends* that these donors be approached for possible support for the Inter-regional Study as an extension of FAP 25.

Proposals for the Terms of Reference for the full Inter-regional Study is outside the scope of the CAT, but the CAT is prepared to assist in this task if so requested.

4.3 Institutionalization of the SWMC

The SWMC is presently part of the Water Resources Planning Organisation (WARPO) in Dhaka. The CAT has been informed that the GOB now plans to

institutionalize the SWMC as part of the River Research Institute (RRI) in Faridpur.

The SWMC plays a key role in the development, maintenance, updating and application of the General Model and the regional models used in the FAP. Throughout the FAP there has been a very close interaction and coordination between the SWMC, the involved GOB authorities and the FAP projects concerned with modelling, partly through the coordination activities of FAP 25, but increasingly so as a natural day-to-day cooperation mechanism. This interaction has been necessary to ensure uniformity of approaches, mutual assistance and coordination in the provision and control of data for the models, and exchange of experiences of model applications and interpretations.

Detailed feasibility studies are expected to be taken up in many of the regions in the years to come. Practically all these studies require modelling. There is no reason to expect that the need for close daily interaction between these studies and the SWMC will diminish in the next phase when detailed answers must be provided from the models.

It is not the responsibility of the CAT to advise the GOB on the general issues relating to the institutionalization of the SWMC. A future of the SWMC under the umbrella of the RRI can undoubtedly be argued. The CAT is concerned, however, about the possible consequences in terms of the physical location of the SWMC if the implication would be relocation of the entire SWMC from Dhaka to Faridpur. The mentioned close interaction and coordination between the SWMC and the modelling activities of the FAP will only be possible if adequate modelling competence and capacity is retained in Dhaka. Obviously some exchange of information and data between Dhaka and Faridpur may take place through modern means of communication, but this can only be a supplement to the daily personal contact. Hence it is the opinion of the CAT that a section of the SWMC must remain in Dhaka if the achievements of the FAP in modelling are to be sustained.

An added concern in this respect is the future institutionalization of the FMM. In the Terms of Reference for this component it is envisaged that the likely end-user would be the WARPO (planning aspects) and the Flood Forecasting and Warning Centre of the BWDB (real-time operation), but that the FMM would be maintained and updated by the SWMC.

At the present time no firm recommendations for the future institutional structure of the water resources sector have resulted from FAP 26.

4.4 Data Base, Data Management and Data Processing Software and Formats

Many FAP studies have collected secondary data from various GOB agencies and built up data bases serving their particular requirements and to different degrees of complexity. Other FAP studies (FAP 11 and FAP 19) are expected to provide general recommendations and support the establishment of database and manage-

ment systems for the benefit of FAP and beyond. All FAPs are supposed to handover their data to GOB upon completion of their studies. However, there is no specification on how, to whom and in which format such handover shall take place.

The third CAT report addressed this question of flow of data and information between the FAP projects, SWMC and various GOB institutions and the possible proliferation of data bases and data processing software. It was recommended that FAP 25, as part of its coordination, made recommendations to MIWDFC on data base and processing software and formats.

The CAT notes that there is only little progress on this issue. FAP 25 has held various meetings with BWDB and WARPO and the issue has also been brought up in the informal coordination meetings and the FAPMCC meetings. Further, FAP 25 has reviewed the January 1991 report of an Inter-Agency Committee on Data Improvement. Among its recommendations the committee proposed:

- to establish a Central Data Register Office at MPO (now WARPO) for all water related data;

- to introduce standard format diskettes in all data collection and data user agencies to allow easy entry and retrieval of data;

- to let WARPO prepare specifications for necessary hardware/software to be gradually procured by all relevant data agencies.

Early August, 1992 FAP 25 proposed to FPCO that WARPO be requested to initiate follow-up actions on the above recommendations.

The CAT is of the opinion that the Inter-Agency Committee report is a good basis for further action. Such action is now highly due if GOB should benefit fully from the comprehensive efforts of a number of FAP studies on data scrutiny and processing.

The CAT *recommends* that the committee established early November, 1992 to look into the question of flow of data and models between GOB and the FAP studies, see section 10.2, addresses the issue. In its report to be submitted by January 1, 1993, should make proposals to initiate follow-up action on the Inter-Agency Committee report.

5. PROVISION OF DATA

5.1 General

The question on provision of good quality topographic and hydrometric data has been addressed during all the previous CAT missions as a matter of great concern to the CAT. The CAT notes with satisfaction that good progress finally seems to have been made for the benefit of the FAP, if not to the ongoing studies, then at least to the feasibility studies that may follow.

5.2 Topographic Data

As reported in section 7.3, FINNMAP has finalized their second order levelling activities in the Jamuna corridor and prepared photomosaics for three pilot areas. However, the results are still preliminary pending the approval of SOB, which is expected in early 1993.

While the second order levelling results have been made available, the photomosaics for Jamalpur, Tangail and Serajganj have not, and FAP 3.1 and FAP 20 are still forced to undertake their work on the basis of old maps.

Following SOB's expected confirmation of the finding of FINNMAP, of the observed 20 cm difference in datum between Jamuna right and left bank, efforts will be required to adjust existing benchmark levels east of Jamuna. This may require additional resources in SOB.

In the NE region the SOB is carrying out comprehensive second order levelling for FAP 6. The survey is expected to be finalised in the present dry season.

FINNMAP is carrying out a second order levelling survey in the coastal area, covering a large part of the SW area and parts of the SE region. It is expected that this survey is finalised in the present 92/93 dry season. If normal procedures are followed, these data will not be available before they have been officially approved by SOB. This may in turn require SOB checking in the field. The CAT *recommends* that FPCO takes action to obtain a release of preliminary data in batches, similar to the arrangement made in FAP 18 for the Jamuna area. The CAT would like to mention that, in principle, SOB checking of data could be done independently of and in parallel with the FINNMAP survey.

5.3 Hydrometric Data

The importance of the quality of hydrometric data has been discussed in the previous reports of the CAT and it is the impression of the CAT that this is now appreciated by all involved parties.

Through the SWSMP Danida has provided support to the BWDB Hydrology during the 1991 and 1992 monsoon seasons as basis for the model development

at the SWMC. Since the last CAT mission the UNDP support programme to BWDB has been initiated. However, partly due to lengthy procedures for procurement of equipment, this programme is not likely to become effective before the 1994 monsoon season.

The CAT understands that the SWMC is presently preparing recommendations to BWDB Hydrology to include a limited number of additional hydrometric stations in their routine programme. These stations are typically boundary stations for some of the regional models and are very important for the continuity in modelling efforts beyond the present phase of the SWSMP. In connection with the UNDP upgrading of the hydrometric network it is expected that requirements in relation to modelling be duly considered.

The CAT *recommends* that Danida provide the necessary financial support to include these limited additional stations in the 1993 monsoon programme, whereafter the UNDP programme is expected to become fully effective.

An extensive morphological field measurement programme has been initiated under FAP 24. The CAT is concerned about the sustainability of this programme after the departure of the consultants, and *recommends* that GOB (through the BWDB) takes steps to ensure a lasting effect of this important programme.

As part of FAP 18, FINNMAP has levelled 50-60 BWDB temporary benchmarks. The CAT *recommends* that once the SOB has finally approved the second order levelling results, BWDB should compare with their information on datum level and make corrections as required.

6. MODELLING TECHNOLOGY

Reports on the MIKE 11 modelling technology were given in the first three CAT mission reports. The need for these comments has diminished as the models have been developed and transferred to the FAP consultants. In this fourth CAT mission report our comments are minimal.

6.1 MIKE 11 River Modelling System

The NAM rainfall runoff, hydro-dynamic, sediment transport/dispersion and quasi steady state modules are now all available under the UNIX operating system.

With the issue of MIKE 11 version 3.01 run times have been improved with a factor 2. When using a 486-microcomputer instead of a 386-microcomputer a further improvement in run time with a factor 3 can be achieved.

Description of structures within MIKE 11 is still causing problems to FAP users and this is regarded as a serious issue by the CAT. The CAT feels that DHI, who has developed the software, should give higher priority to this issue. At present, SWMC is provided advice to model users and some modifications to the software and documentation are in hand.

6.2 Morphological Modelling

SWMC reported preliminary results of a morphological study of the major rivers using the MIKE 11 morphological component during the Third CAT Mission in December 1991.

The model represented a much simplified picture of the Jamuna, Ganges and Padma rivers and the CAT made various suggestions which would increase the value of this exploratory work. Some of the suggestions were taken up but the sensitivity testing was not carried out.

In cooperation with the SWMC, the model has since been taken up by FAP 1 and has been used to make predictions of mean bed and water level changes in the Jamuna as affected by works which may be suggested by FAP 1 and FAP 3. The model has also been used to assess the effects of the Jamuna Bridge crossing.

In verifying the model a large and arbitrary multiplier was applied to the well established Engelund-Hansen sediment transport function. The CAT queries the justification for this and suggests that the real reason for the initial lack of fit could be associated with any or all of the following factors:

- accuracy of measurements;
- the particular sediment transport theory used;
- the sediment size assumed in the modelling;
- whether sediment grading is an important facto;

- the effects of the flow resistance formulation;
- the use of an appropriate hydraulic mean radius for sediment transport calculations;
- the use of an appropriate bed width for sediment transport calculations.

The CAT requests that SWMC should look into this issue.

The CAT stresses that one-dimensional morphological modelling alone cannot supply definitive answers relating to the natural development of river channels as affected by the FAP and others proposals. In particular, the modelling does not take into account and cannot predict:

- changes in channel width
- changes in cross-sectional shape
- changes in channel pattern
- lateral movement of channels

One dimensional morphological modelling gives some insight into the future behaviour of rivers but is obviously limited in its scope of application. This is particular so when simulating large sand bed rivers which are inherently "mobile".

FAP 4 has done sediment transport modelling with the SWRM for the non-cohesive sand fraction. Cohesive sediment transport modelling and morphological modelling (with bed level updating) has not been carried out. FAP 4 finds that in practice morphological modelling on a regional scale is an unrealistic undertaking. The initial intention of the SWMC to develop regional morphological models has been too ambitious. The SWMC has reached the same opinion, as it was already stated in Appendix 5 of the report of the Third CAT Mission. Based on the experience over the last year, SWMC has prepared an updated note on approach to and status of morphological modelling at the SWMC. The note is included as Appendix 6 of the present report.

Also FAP 21/22 underlines the limitations encountered with the MIKE 11 package for the morphologic computations in a complex system.

FAP 21/22 has therefore developed a simplified mathematical model for studying basic morphologic evolutions induced by various recurrent measures. It is concluded that appropriate modelling would include local, small models with a few branches, connected with a few nodal points; schematized rectangular cross section, constant roughness coefficient. As underlined by the Consultant, results of the computations are qualitative. The CAT supports these conclusions.

7. MODELLING IN FLOOD ACTION PLAN COMPONENTS

7.1 Timing of Model Supply and Use

Since the Third CAT Mission model development at the SWMC has suffered some delay. For each of the models Table 7.1 shows the revised delivery dates of full and verified models as compared to the schedule at the time of the Third CAT Mission. The delays are typically in the range from 3-5 months. The reasons are the same as previously and include shortages in staffing, additional efforts on data collection and processing and difficulties encountered in the transition to the UNIX operating system.

Until now the delays have had no serious implications for the regional studies. Very recently, FAP 6 has expressed its concern with respect to late delivery of the full NERM. The CAT *recommends* that this matter be addressed directly by FAP 6 and SWMC to see whether an intermediate version (between a pilot and a full model) can be made available to FAP 6 in due course.

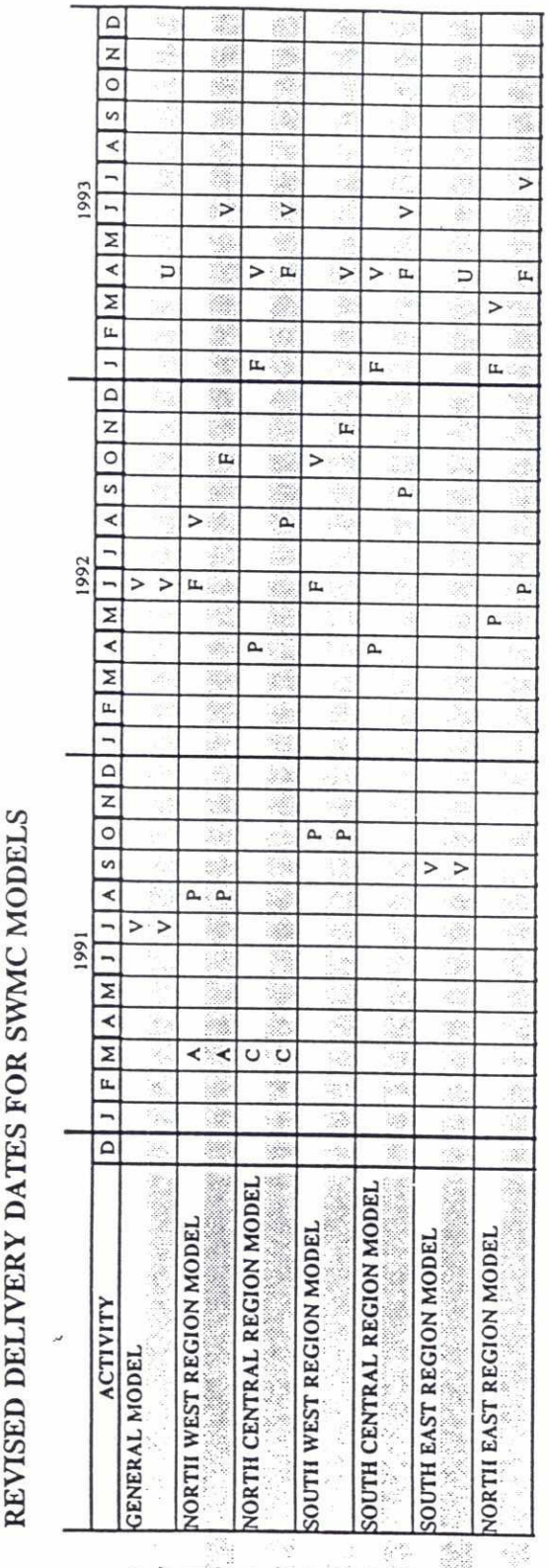
Though limitations and some problems in the use of the models have been pointed to by several FAP consultants they have generally been overcome. Overall, the regional consultants have found the models, and any sub-models generated by themselves based on the MIKE 11 software, to be indispensable tools in preparing their regional development plans.

The regional FAP consultants have used or are using the pilot stage version of the regional models. With the exception of FAP 6 (see section 7.2), the regional FAPs generally find that the accuracy achieved with these models is within their requirements for planning and prefeasibility studies, i.e. in the order of 50 cm on peak water levels and 25% on peak discharges. The issue of model accuracy requirements is further addressed in Chapter 10.

Within the revised schedule of model development full and verified stages of all the models will be available from spring or early summer of 1993, in due course for any feasibility studies that may arise from the regional water resources plans.

In the case of the SE region, where the consultant has started feasibility studies, a verified model already exists. The SWMC has promised that an update version will be available by January 1, 1993 (associated technical report in April 1993).

Table 7.1: Revised Time Schedule for Delivery of Models From the SWMC



7.2 Regional Studies

FAP 2: North West Regional Study

The draft final report for this study was submitted in October 1992. The final report is due 31 January 1993.

FAP 2 has continued to co-operate with SWMC in developing the NWRM. Emphasis has been on the sub-regional models for the lower Atrai basin and the middle/lower Bengali. FAP 2 has developed a separate model for the Gaibandha Priority Project Area and a dedicated model for the proposed Bengali Floodway to study drainage from the upper Karatoya direct to the Jamuna.

The FAP 2 consultant has followed strictly the modelling approach proposed by FAP 25 and has undertaken long term simulations for the "without project" scenario and the preferred combination of options. The identification of preferred options was based on 10-year simulations.

Problems have been faced concerning the use of structures within MIKE 11 and water level data for the Baghabari gauging station and in the Lower Atrai.

FAP 2 has recommended design and implementation of the Gaibandha Project and a feasibility study of the lower Atrai basin with particular reference to polders C and D.

In terms of modelling and related activities FAP 2 has recommended:

- further detailed modelling at the feasibility stage;
- further work on post-processing facilities for MIKE 11;
- further research into the performance characteristics of submerged embankments and their simulation in computational models;
- physical models of local areas;
- morphological studies relating to proposed projects.

FAP 3: North Central Regional Study

The final draft report was submitted in November 1992. No team members from FAP 3 were in Dhaka during the Fourth CAT Mission.

Reports available to CAT members included Main Volume, Regional Water Resources Development Plan, and the Preliminary Supporting Report II, Water Resources. The Resident Model Coordinator has submitted comments to the consultant and to FPCO on the PSR II report.

The modelling carried out by FAP 3 was constrained by the tight time schedule for the NCRS and the late initiation of the NCRM at the SWMC. FAP 3 was not able to follow the modelling approach developed by FAP 25. However, with these

constraints in mind, the modelling approach followed by FAP 3 was generally sound.

FAP 3 may continue with feasibility studies concerned with strengthening of existing embankments and establishment of new ones along the left bank of Jamuna (FAP 3.2 and FAP 3.3). For such feasibility studies the consultant(s) should use the approach developed by FAP 25, including long term simulations with the detailed model(s).

These studies, as indeed FAP 1, should of course consider potential morphological and hydrological changes in the Jamuna, but would benefit from the more comprehensive analysis provided by the morphological component of the Inter-regional Study (Morphology Study) proposed by the CAT.

FAP 3 has proposed that primary data collection for improving/developing a subregional model in the FAP 3.2 area be undertaken in due course. Some surveys have already been done in the 1992 monsoon. It is indicated in the draft final report that the FMM component of FAP 25 should deliver a subregional model for the FAP 3.2 area. The CAT notes that FAP 25 has made no commitment in this respect, though it is believed that the regional scale FMM for the NC region could be of use to the consultants undertaking feasibility studies in the region, depending on the exact schedule of such studies vis-a-vis the FMM schedule.

FAP 4: Southwest Area Water Resources Management Project

At the time of the Third CAT Mission FAP 4 had only recently started. With respect to modelling, the relevant report available to the CAT is the Interim Report of June 1992, notably Annex 1 - Hydrology, Annex 4 - Hydraulic Modelling Studies, and Annex 5 - Morphological Studies. The Resident Model Coordinator has provided comments to the consultant and FPCO on Annexes 1 and 4.

The SW area is the area, where the proposed methodology of FAP 25 including 25-year simulations is most troublesome due to the importance of tidal flows, demanding the use of small time steps. Because salinity intrusion is one of the major problems in this area FAP 4 has also done extensive dry season modelling. Finally, the SW area model is the largest of the regional models, because of the need to merge the SW and the SC regional models of the SWMC to study some of the proposed interventions directed towards alleviation of salinity intrusions.

Several modelling approaches were considered, including both tidal and non tidal. Finally, it was decided to do simulations including the tide and using hourly timestep.

The consultant has managed to follow the approach suggested by FAP 25. The SWRM and the SCRM has been combined into one Southwest Area Model

(SWAM). A 25-year simulation has been undertaken for the existing hydraulic situation and design statistics have been established on that basis.

The development options modelled include:

- reduction of salinity intrusion in the SW region by either flow augmentation in the river Gorai or through inter-basin transfer from Arial Khan via Madaripur Beel Route;

- alleviation of drainage congestion in the polder areas including effects on siltation patterns;

- embankments along Padma and Lower Meghna right banks, analysed for the 1988 flood;

- effects of sea level rise on flooding (1988) and salinity intrusion in a normal dry season.

Though not finally decided, FAP 4 also intends to do 25-year simulation for the regional development plan.

Apart from the general problems mentioned above, the major problem faced by the consultant on modelling is the uncertainty on boundary conditions (gauge datum levels) along the coast line, where even small water level differences determine net flow circulation in an intricate river network. The consultant has used a 2-D hydrodynamic flow model (MIKE 21) for the Bay of Bengal to improve the understanding of hydrodynamics and salinity conditions along the coast line.

FAP 5: South East Region Water Resources Development Programme

Only very limited modelling has taken place under FAP 5 since the Third CAT Mission. However, at the SWMC considerable effort has gone into further improvement of the model. The SERM is now available under UNIX and the northern and southern sub-models have been merged into one model. New river cross sections are added to increase resolution of the model. A thorough update verification exercise at the SWMC is underway. The calibration of the Ramatkhali regulator has proven difficult, because of lack of reliable data. The SWMC has promised that this updated version is available to FAP 5 not later that January 1, 1993.

FAP 5 intends to follow the proposed FAP 25 methodology in the continuation of the project, including feasibility studies for Gumti II and Noakhali North projects and preparation of the final regional water resources development plan.

At present, FAP 5 is updating their hydrologic database for long term simulations (rainfall, water levels and river flow). FAP 5 is facing some problems with obtaining long term boundary conditions, notably with some of the inflows from

the Indian catchments. Synthesised records would be produced for three stations for the period 1964-91.

Further, FAP 5 considers the use of the Salinity Intrusion Model (for the Lower Meghna and the estuary), as developed by the SWMC, to establish salinity profiles in the Lower Meghna as required for deciding the possible operation of the Ramatkhali regulator under different upstream water abstractions.

The major problem being faced by FAP 5 in relation to modelling is the uncertainty on the exact gauge datum of the Daulat Khan station. The datum was estimated by SWMC to need a correction of 75 cm during the calibration of the General Model. FAP 25 has applied the same correction and the simulation results at Chandpur for the period 1964-89 confirm the adequacy of this correction. However, the proposed correction was based on a model in which the Lower Meghna was not represented to the same detail as the rest of the river system. Work currently being carried out on a more detailed model of the Lower Meghna and the South Central Region indicate that this correction is probably too large. The final decision on the estimated correction should await the determination of the true datum of Chital Khali through the levelling proposed and carried out by FAP 5.

This correction will be incorporated in the General Model update to be published in April 1993. If required, SWMC has agreed to do preliminary recalibration of the Lower Meghna as well as a 25 year model run to provide boundary conditions for use by FAP 5 as soon as possible.

Finally, FAP 5 has expressed some concern to the CAT with respect to the extent to which design conditions in the Gumti-II area may be affected by possible upstream developments, including submersible embankments in the NE, an Upper Meghna right embankment and the Jamuna left embankment. The CAT sees this valid concern as a support for the Inter-regional Study proposed in the two previous CAT reports and reiterated in this, see Chapter 4.

FAP 6: Northeast Regional Water Management Project

The major effort of model development and calibration in FAP 6 has been under the domain of the SWMC. FAP 6 has contributing additional funding to the primary data collection of the SWMC in the NE region and assisted in developing the overall approach to modelling with due consideration to the specific constraints on modelling in the region. The FAP 6 modelling team was located in the SWMC until June, 1992.

The cooperation between FAP 6 and SWMC on primary data collection has been very good. FAP 6 has supported a comprehensive survey programme (cross section and hydrometric survey via SWMC/BWDB and second order topographic levelling by SOB). FAP 6 considers to develop a digital elevation model for mapping of flood extent under different hydrologic scenarios.

A comprehensive index and mapping of hydrometric data as well as a hydrometric data base have been prepared.

The available information indicates that, until now, FAP 6 has only done limited modelling themselves and no reports have so far been produced on modelling under FAP 6. The NERM was transferred to FAP 6 office in June 1992. The two sub-models have been merged into one model and extended upstream to Amalshid to include upper Kushiyara and Surma rivers. Simulations have been made of the Kushiyara dredging scheme.

Very recently, FAP 6 has expressed its concern that the full NERM will not be available in due course for preparation of the regional plan and for undertaking the long term simulations as proposed by FAP 25. At present the SWMC expects the full model to be available by April 1993, three months late of the original schedule.

FAP 6 has also expressed concern about the uncertainty and inconsistency of the vertical datums in the region, and hence has some reservation with respect to the accuracy of the pilot stage of the NERM and its ability to predict absolute water levels with sufficient degree of confidence. However, for relative comparison of alternative options, FAP 6 still intends to use the model. FAP 6 also considers to do long term simulation of their regional development plan, if a satisfactory accuracy can be achieved with the model. FAP 6 has experienced, like FAP 19, that definitive information on model schematization and cross section locations is often difficult to obtain from SWMC.

While appreciating that the model results at some locations are very different from observations, the CAT is of the opinion that overall model performance is satisfactory for planning and prefeasibility purposes. The technical report from the SWMC on the pilot model calibration indicates where poor agreement is likely to be due to deficiencies in model set-up and where the observed data can be suspected to be in error.

It is the impression of the CAT that a solution on these issues may be achieved through a closer cooperation between FAP 6 and SWMC on modelling, similar to the extensive cooperation that other regional FAPs have had with the SWMC. The CAT *recommends* that, in this context, the SWMC and FAP 6 jointly consider the possibility of making any intermediate version (between the pilot and the full model) of the NERM available in due course to allow its use in the preparation of the regional water resources plan under FAP 6.

7.3 Other FAP Studies

FAP 1: River Training Studies of the Brahmaputra River

Reports available to the Fourth CAT Mission included :

- Second Interim Report dated December 1991

- Annex 2 Mathematical modelling
- Annex 4 Morphology

The final report was due in November 1992 but was still being finalised during the Fourth CAT Mission. The Master Plan report is due at the end of December 1992 and reports on physical and mathematical modelling are due at the end of January 1993.

FAP 1 has followed the methodology proposed by FAP 25 and has undertaken long term simulations for various flood control options along the Jamuna including embankment set back distances and the effects of the Jamuna bridge. FAP 25 has made comparison of FAP 1 and FAP 25 simulations in the Jamuna. There is a reasonable agreement although local differences are observed. FAP 1 was particularly concerned with peak water levels, used more river cross sections than FAP 25 and has thus made their own calibration of the GM.

Within the limitations of 1-dimensional morphological modelling, see the third CAT report, section 5.2, FAP 1 has in cooperation with the SWMC investigated long term changes in mean bed levels along the Jamuna, Ganges and Padma rivers caused by engineering measures which could be considered along the Jamuna, see also section 6.2 of this report.

FAP 3.1: Jamalpur Priority Project

FAP 3.1 has submitted the draft final feasibility report in October 1992. A hydrodynamic model based on the MIKE 11 software has been used to simulate flooding conditions with alternative development options and without any projects.

The alternative options have been costed and potential benefits estimated taking into account among others flood proofing, drainage improvements, embankments and hydraulic structures such as inlet, outlet and bridges.

Generally, the modelling exercise of FAP 3.1 has been hampered by the lack of sufficient hydrometric data. The consultant undertook his own primary data collection in the 1992 monsoon, which has compensated to some extent for this deficiency. Boundary conditions have been supplied by FAP 25 - FHS and FAP 3.

The CAT notes that no assessments have been done on the morphological problems which can arise in the Jamalpur Priority Project such as:

- accretion in drainage channels
- maintenance of inlet works
- stabilization of plan form river courses

All these factors may increase the cost of the project.

The CAT suggests that exchange of views with FAP 22 (Active Flood Plain Management) would be beneficial for FAP 3.1 concerning the schematic computed simulations of accretion-erosion in drainage channels and inland rivers.

At least qualitative morphological trends should have to be evaluated and tentatively related cost estimated for all the hydraulic structures.

FAP 10: Flood Forecasting and Early Warning

During the 1992 monsoon forecasting was affected by lack of real time data from India, because water levels were lower than the limit above which India should submit data.

Due to delay at SWMC in preparing the pilot version of the NCRM, regional level forecasting was not initiated before late July. It is stressed by FAP 10 that annually updated models should be available not later than early May, before the monsoon season starts.

The FAP 10 project terminated by November 30 , 1992. Draft TOR for a project continuation - Development of Flood Warning Services to Improve Public Safety - has been prepared by the CTA and reviewed by FPCO and the Panel of Experts. Final TOR has not yet been approved. Possible donors have been identified, but no financing is secured yet. The draft TOR is available with FAP 25 and have been reviewed.

The overall objective of the FAP 10 continuation is "to provide improved information to aid national preparedness for floods as a major contribution to the non-structural measures aimed at mitigating flood impacts". This would be achieved through the following main activities:

- development of telemetry facilities;
- expansion of weather radar;
- flood modelling studies;
- improvement of forecast outputs and public awareness;
- establishment of data transfer links between Bangladesh Meteorological Department and the Flood Forecasting and Warning Centre.

The further development of flood forecasting models (the third activity), relevant to the FMM development under FAP 25, the SWMC and FAP 19, would include, inter alia:

- improvement and refinement of the General Model;

- development of regional flood forecasting models, for example for the NW and NC regions, including improvement and refinement of the existing models:

- development of local/regional DEMs and interfacing with MIKE 11 for the forecasting of area/depth inundations;

- adjustments of the FMMs developed by FMM for real-time application.

The analogy of these anticipated activities with those carried out by the FMM component under FAP 25 is striking, and the need for a very close cooperation between the two projects and with SWMC from the very beginning is evident.

The CAT *recommends* a closer examination of the TOR of FAP 10 to avoid unnecessary duplication of activities between FAP 10 and FAP 25 (FMM). Such examination could be part of possible donors' appraisal of the proposed continuation. At the time of such appraisal the FMM development under FAP 25 may have progressed significantly and could thus provide very valuable input to the final TOR of FAP 10.

FAP 16: Environmental Study

FAP 16 has submitted final draft guidelines and manuals for environmental impact assessment (EIA) in May and October 1992. Final "Guidelines for Environmental Impact Assessment" have been issued by FPCO in October 1992. Case studies are ongoing to test and demonstrate the use of the EIA Guidelines to other FAP consultants.

Modelling as an EIA tool is not mentioned in the Guidelines, but has been included in the second volume of the draft EIA manual. The SWMC is assisting FAP 16 with runs of the NCRM to study possible downstream effects of developments in the Tangail Compartment.

Considering that the environment of Bangladesh is intimately linked to the behaviour of the major rivers, the CAT finds it surprising that morphological issues are not highlighted as important. In fact, the Guidelines and draft manuals consist of a long checklist of items to consider, apparently without clear priorities. In this list sedimentation and erosion is included as one of a large number of sub-items in the appendices. 'River morphology' is not mentioned, and nor is the risk of drastic morphological in the short (abrupt change) as well as in the long term.

The CAT considers morphological and hydrological change the single most critical environmental risk associated with the FAP. Changes in the morphology of the major rivers may have significant impact on water level characteristics, and hence on the overall environment. This should be highlighted in the EIA Guidelines and Manuals.

The CAT further wishes to emphasize the need for assessments of the overall, nation-wide environmental effects of the FAP. Such assessments require the vehicle of the proposed Inter-regional Study which addresses the combined effects of FAP interventions, as opposed to EIA of individual projects within specific regions.

FAP 18: Topographic Mapping

The aerial photography, second order levelling and mapping activities by FINNMAP under FAP 18 have been finalized. The aerial photographs of the Jamuna corridor are available through FPCO as are the preliminary results of the second order levelling. The photomosaics will not be released prior to the official approval by SOB. The actual status is as follows:

a) Aerial Photographs

- 1:50,000 data has been supplied to FPCO. Negatives are with FPCO;
- 1.20,000 data has been supplied to FPCO. Negatives are with SOB.

b) Second Order Levelling

- all levelling completed by FINNMAP, including also 50-60 BWDB temporary benchmarks;

- absolute levels have been calculated and supplied to FPCO and to SOB. The data are available to all FAP consultants. FINNMAP survey has indicated that there is a datum difference across the Jamuna, the datum of the right bank being 20 cm higher than that of the left bank;

- SOB has agreed in principle that the west bank datum should be the new reference datum but will check the FINNMAP survey through independent river crossings this December and January. The FINNMAP data are not official before this checking has taken place.

c) Pilot areas

- photomosaics of Jamalpur area (1:20,000 with 0.5 m contours), Tangail and Sirajganj areas (1:10,000 with 0.25 m contours) have been prepared by FINNMAP;

- blueprints hereof was delivered to BIWTA mid November, 1992 and should now be with SOB for final checking, expected in mid December 1992. However, absolute levels can not be determined before SOB has done the survey crossings of Jamuna meaning that final approval by SOB would be delayed until February 1993 at the earliest;

The implications of the observed datum difference between Jamuna left and right bank for modelling can not be assessed in detail by the CAT. It is the general opinion of the CAT that it is not critical and that it has been compensated for in the calibration of the model. Anyhow, the CAT *recommends* that the findings of FINNMAP, once approved by the SOB, be taken into account by SWMC before the next update of the General Model. To the extent that boundary conditions for the regional models, as obtained from the General Model, are not affected by this datum difference, neither would the regional level modelling itself be affected.

FAP 19: Geographic Information System

The tasks being accomplished by FAP 19 in relation to modelling include:

a) Set-up of a methodology for using GIS techniques to establish digital elevation models (DEM) and demonstration for selected pilot areas, including:

   * a national level DEM on a 300 x 300 meter grid, generated from MPO 1 km grid spot heights;

   * a regional level DEM on a 300 x 300 meter grid, for the western part of the North Central region generated from spot heights from BWDB's 4 and 8 inch to a mile maps and establishment of a continuous land surface;

   * a local/compartment level DEM on a 40 x 40 meter grid for the Tangail area using spot heights from BWDB's one foot contour maps.

b) Comparison of historical digital elevation data using 1960s BWDB elevations from one foot contour maps and recent surveyed elevation data from FINNMAP. Comparison has been done in the Gumti-II area in the SE region (FAP 5), to the knowledge of the CAT with promising results;

c) Establishment of methodology for using GIS to compute area-elevation curves as input to MIKE 11;

d) Establishment of methodology for using GIS techniques to prepare flooded area and depth maps from MIKE 11 and testing in Tangail area. Method used involve "simple" interfacing of MIKE 11 water level surface and DEM generated land surface;

e) Cooperation initiated with FAP 4 (SW area) to develop such flooded area and depth maps.

Draft technical reports on points a)-d) will be available very soon.

Under assignment with FAP 1 and based on satellite imageries from 1973-92, FAP 19 has prepared a very interesting computer display series showing bankline changes in the Jamuna.

It is the experience of FAP 19 that it has been difficult to obtain definitive information from the SWMC on the model schematization and information on the spatial location of cross-sections is often incorrect.

To the knowledge of the CAT, checking of the location of morphological cross-sections is a major component in the field activities under SWSMP-II and signifi-

cant improvements have been achieved. The SWMC should coordinate its efforts with review of past measurements and observations done under FAP 24 and by BWDB Hydrology under the UNDP-sponsored support programme. With respect to model performance, incorrect cross-section locations may to some extent be compensated for in the calibration process. In this respect the models have been valuable tools to identify possible incorrect locations.

FAP 19 has found that using a MPO-grid based DEM for flood storage elevation characteristics gives significantly different results from a DEM based on detailed spot height from BWDB maps. One of the major reasons for this is that the former uses only one point per 100 ha as compared to the latter using one point per 3 ha.

Close liaison is maintained between FAP 19 and FAP 25 with respect to FMM development. The expatriate software specialist of FAP 25 worked under FAP 19 in developing the methodology for MIKE 11-DEM interfacing using GIS technology. FAP 19 has already agreed, on behalf of FAP 25, to supervise the DEM development for the eastern part of the NC region.

In its forthcoming Interim Report FAP 19 will present possible future demonstration projects/pilot studies for GIS technology. Under consideration are continued work on the MIKE 11-DEM interfacing in a close cooperation with FAP 25. Another very interesting option being considered, and which would be of great benefit to the FMM development under FAP 25, is the use of ERS-1 satellite data (using the space-borne synthetic aperture radar - SAR) to create flood inundation maps. The frequency of coverage of Bangladesh is approximately every fortnight. A number of national ground stations around the world will receive ERS-1 high rate data. Data for Bangladesh could probably be procured from the stations located in Hyderabad, India and in Bangkok, Thailand.

FAP 20: Compartmentalization Pilot Project

The project has submitted an Interim report including Annex 4 on Mathematical Modelling in September 1992.

FAP 20 conducts a major programme of primary data collection including hydrology, river cross section and topography for both the Tangail and the Serajganj compartments. This programme will continue till end of the project. Efforts are made to observe flood plain inundations.

A calibrated Tangail Compartment Model based on MIKE 11 was available by February 1992 and a verified model is expected by December 1992, when also a calibrated Serajganj Compartment Model would be available.

FAP 20 has not used the modelling approach proposed by FAP 25 including long term simulations. This is partly due to and justified by the present lack of boundary data. It is not believed to be serious for the general validity of the model simulations under FAP 20.

Based on a historic correlation between water level and potential crop damage, the years 1987, 1989 and 1991 have been identified as covering a wide range of flooding conditions and simulations have been carried out for these years.

The Tangail Compartment Model has been used for modelling inlet structures over Lohajang, improvement of existing structure, drainage improvement and water management at sub-compartment level, and an appropriate dimensioning of the main inlet in the Lohajang.

In the continuation FAP 20 intends to study the water management in detail by splitting the existing model into two sub-models to avoid DOS limitation. It will also model the effect of construction of the Brahmaputra Left Embankment (BLE).

FAP 20 expects the model to be a useful tool in the public participation process in the sense that visualisation of model results may lead to improved understanding of the possible consequences of various controlled flooding and drainage options.

For FAP 16, the SWMC has recently carried out simulations of the environmental impact of the Tangail compartment. The results indicate that the downstream boundary of the Tangail Compartment Model may be affected by developments in Tangail. The CAT advises FAP 20 to contact SWMC on this issue.

It is noted that in the continuation there will be a particular close cooperation between FAP 20 and FAP 25 on the development of a tailored Flood Management Model for the Tangail Compartment. Important improvements compared to the existing Tangail Compartment Model relate to a better representation of flood plain inundation and improved description of structures operation.

FAP 21/22: Bank Protection and River Training (AFPM) Pilot Project

FAP 21/22 has submitted the Inception Report in March 1992 and the Interim Report in July 1992.

FAP 21 is the Bank Protection and River Training component of the project. It is mainly concerned with the design and implementation of test "hard points" in prototype scale, such as groynes and bank revetments. Two test areas have been selected:

- Kamarjani site on the Jamuna right bank, just upstream the Manos regulator, for building up and testing three groynes;

- Bahadurabad site on the west part of Belgachha-Ghilabari for bank revetment works testing.

The main design parameters of both structures will be tested beforehand at the River Research Institute (RRI) in physical, movable bed models.

The construction of the groyne structures is planned to start after the 1993 monsoon.

FAP 21/22 intends to use the results of the FAP 25 Flood Hydrology Study as general boundary conditions for the scale model tests. In addition, FAP 21/22 has carried out supplementary data analysis to provide specific information including:

- Construction "window" during low water periods;

- Statistical analysis of rapid variations of the river water levels for studying the induced effects on the internal ground water levels, and hence on the stability of the structures.

FAP 22 is the Active Flood Plain Management (AFPM) component of the project. It is concerned with recurrent measures with the aim of modifying, in a soft way, local morphological planforms, e.g. to divert a river channel away from a threatened bank or to decrease its aggressiveness by reducing both discharge and velocity.

Some promising recurrent measures have been selected on the basis of a literature review and from experience, including:
- surface vanes at a bifurcation;
- artificial cutoff;
- sill;
- dredging.

With reference to section 3.8 of the FAP 21/22 Interim Main Report the CAT *recommends*:

1) to enlarge the review of existing strategies mainly in the following countries: Thailand (Chao Phraya river), India (Brahmaputra), France (Loire and Petit-Rhone rivers) in which bandalling and/or bottom vanes have been tested on a large scale;

2) In a later stage, but as soon as possible, to carry out prototype testing of a recurrent measure, e.g. a potentially attractive floating structure. Data from such tests may be useful for the calibration of both the mathematical model and physical model. In addition, the tests may provide useful field experience for preparation of a possible, more extensive, pilot project.

Finally, the CAT fully agrees that AFPM requires a qualified organization to closely monitor the river developments in order to take quick decisions at an early stage when the recurrent measures are most effective.

FAP 24 River Survey Project

The FAP 24 River Survey Project started in June 1992. Field reconnaissance has been completed and a set of test measurements has been made at Bahadurabad in

October 1992. A revised Inception Report was submitted in November 1992. The EC appointed project advisor has started his duties and has agreed testing procedures with the consultant.

The project has three components ; surveys, studies and training with the surveys dominating the activities and the manpower inputs.

Phase 1 of the study is scheduled to be completed by 31 May 1993. This phase includes deployment and verification of survey equipment over a wide range of flow conditions together with some preliminary studies and training activities.

Phase 2 involves extensive surveys throughout the flood seasons and completion of the studies and training activities.

The FAP 24 consultant is using high tech equipment with the aim of obtaining large quantities of high quality data during his survey programme of the Jamuna.

The CAT *recommends* that the data are compared with those obtained using conventional techniques and are used to identify systematic errors which may exist in these conventional and well used methods. Correction factors may be identified which will enable historic records to be corrected and future readings to be of higher accuracy. The CAT appreciates that deviations between FAP 24 and BWDB measurements may be due to direction of flow through the measured section. As the direction will change over the years, and possibly even during one year, identification of such correction factors may, however, turn out to be difficult and even impossible.

It is important that the lessons learned during the FAP 24 study are sustainable into the future.

The CAT explored the nature and the extent of the anticipated morphological studies to be carried out mainly in phase 2 of the project. It is the view of the CAT that the proposed man month inputs for morphology by no means will permit an extensive study of the morphology of the major rivers; certainly not to the extent that the effects of the FAP Regional Study proposals will be quantified. Furthermore, the results will not be available in time to be taken into account during the feasibility studies of regional projects.

FAP 24 will generate large quantities of data and it is important that decisions are made on a standard database to be used by the Water Sector, cf. section 4.4 of this report. Meanwhile FAP 24 will store data in the HYMOS format.

8. FLOOD HYDROLOGY STUDY

8.1 Status of FHS

The Flood Hydrology Study (FHS) is coming close to an end. The final Main Report including the supporting Annex 1 was submitted in June 1992. This concluded stage 2 of FHS. Meanwhile, country-wide protection scenarios have been analyzed with respect to their effects on water levels in the main rivers, and results have been reported in draft Annex 2 in early September 1992. The final Annex 2 will be issued in December, incorporating comments received from FPCO and PoE on the draft and the results of some additional simulations. The final approval of the FHS in the Review Committee is then expected in due time.

Annex 2 is reviewed briefly in Section 8.2. Some issues requiring further attention are indicated below.

Validation/recalibration of the GM

The Third CAT Mission report (Appendix 7) outlined a number of deficiencies in the calibration of the General Model, observed both for recent years as for the full period 1964 - 1989. Some of these deficiencies have been removed in the 1992 update of the GM, while the following improvements still need to be made:

- improved schematization of the reach at Hardinge Bridge on the Ganges, to avoid underestimation of upstream water levels;
- improvement of calibration for Sengram station on the Ganges;
- recalibration of some stations on the secondary rivers.

The SWMC has agreed to incorporate these improvements in the 1993 update of the General Model. This will also include a substantial improvement of the Lower Meghna. The CAT *recommends* that also the results of the FINNMAP activities under FAP 18 be taken fully into account by SWMC in the 1993 update.

Safety Margins for Design Water Levels

In the Third CAT Mission report it was also recommended that FPCO took decision on the concept of safety margins on peak design water levels, proposed by the FHS to take into account the effects of random morphological processes, model errors and shortness of hydrological records. For the main river system specific safety margins for various return periods have been proposed and which should be considered within the overall safety requirements including freeboard for wave run-up. The FHS recommended that the methodology applied to derive these safety margins be adopted also for the regional rivers.

The importance of the safety margin issue increases when the regional FAPs enter the stage of feasibility studies, and it is recommended that FPCO takes a decision on this issue shortly, considering the importance of a unified approach in all the FAPs for the assessment of design criteria.

8.2 Analysis of Country-wide Protection Schemes

As part of the final stage of the Flood Hydrology Study a number of potential FAP development scenarios have been investigated through long term simulations with the General Model (FHS Report Annex 2).

The CAT has reviewed draft Annex 2 and concurs to the general approach for the analysis of country-wide protection scenarios. The simulation programme for this analysis has been prepared on the basis of discussions with the FPCO, the PoE, FAP 1 and the regional FAPs. Annex 2 rightly indicates that the results of the analysis must be considered indicative and may be refined as more detailed information becomes available on actual location of future embankments and structures.

The CAT finds, however, that these simulations have provided useful insight into the possible range of water level changes in the major river system in response to various FAP interventions. The CAT *recommends* that the final FHS Annex 2 be made available to the regional studies before initiation of feasibility studies.

Morphological changes induced by the proposed protection works may interfere with the computed impacts, because the General Model does not take such changes into account (fixed bed model). However, it takes a relative long time span for such changes to develop as shown by indicative morphological computations carried out recently by SWMC and FAP 1 for the Jamuna. The design flood may nevertheless occur 'the day after tomorrow'. Design levels should, therefore, meet at least the levels derived from the fixed bed model simulations, which represent the current situation. Where induced morphological developments may lead on the longer term to accretion some margin must be added to design levels, but no advantage can be taken of potential long term river bed degradation.

Results obtained could only be compared to some extent with results from other studies. It is suggested consideration be given in the final Annex 2 also to the results of the Jamuna Bridge Study with respect to the effects of this bridge on upstream water levels.

Results of the FHS in the form of 25-year time series of water levels and discharges at selected locations on the major rivers are available to other FAPs, for the existing situation and one likely future protection scenario. For a number of other protection scenarios 5-year time series are available. Such data can be used as boundary conditions for simulations with the regional models.

8.3 Implementation of FHS Methodology by Other FAP Projects

Due to the interaction of the various flood causing factors, the definition of design events of a given return period in terms of standardised boundary conditions is impossible. The CAT therefore recommended a methodology for estimating design water levels at regional level to overcome this problem, as follows:

- running of the regional models for a 25 year period (1965-89), at least once for the present (baseline) conditions and once for the ultimately adopted regional flood alleviation scheme(s);

- study of various flood control options on the basis of simulations for a reduced number of selected flood seasons;

- statistical analysis of the results, based on recommended distributions and aimed at assigning return periods to historic peak, seasonal or sub-seasonal values of selected design variables.

The adoption of this methodology on regional level has been discussed with the regional FAPs as part of the coordination activities.

FAP 2 has followed strictly the proposed methodology and has undertaken long term simulations (1965-1989) for the "without project" and "with project" scenarios. The identification of preferred options has been based on 10 year simulations.

FAP 3 could not follow the proposed methodology due to the late initiation of the NCRM development at SWMC, but it is expected this will be done during the feasibility studies.

Though complicated due to tidal boundary conditions of the SWRM and SCRM, FAP 4 has managed to complete a 25-year simulation for the existing hydraulic situation, on the basis of which design statistics have been established.

FAP 5 has also decided to follow the proposed methodology in the continuation of the project (feasibility studies). At present FAP 5 is updating their hydrologic data bases for long term simulations.

FAP 6 considers the Pilot Model not accurate enough to justify a 25-year simulation and awaits the Full Model (April 1993) before committing themselves to making these long term simulations.

Thus, it may be concluded that the methodology proposed by the FHS, in general, has been or will be adhered to. Results achieved under FAP 2 and FAP4 have proved that the methodology is justified and beneficial. With the running of the latest MIKE 11 release (3.01) on a PC 486-computer run times of the regional models for 25 years have become manageable.

8.4 Follow-up on the Flood Hydrology Study

The hydrological basis of the engineering design criteria in the major rivers may be revised during the course of the FAP as more exact information becomes available on the actual regional flood control options and their likely combination. Also the General Model input data and performance may be improved, e.g. with the FAP 18 results, after SWMC update of the GM and when survey data from FAP 24 become available.

A revision of the hydrological basis for design criteria along the major rivers should follow the next SWMC updating of the General Model. This updating can still be carried out within the existing scope of FAP 25. Subsequent updating(s) may need to be carried out by the SWMC.

9. FLOOD MANAGEMENT MODEL

9.1 General Project Status

The Flood Management Model (FMM) commenced in mid October 1992 following approvals from GOB and the donor agencies.
Computer hardware and software have been purchased and installed in the project office.

The FMM Inception Report is due on 31 January 1993 with First and Second Interim Reports on 31 August 1993 and 31 March 1994 respectively. The Final Report is due 31 October 1994.

9.2 Linkage with Other FAPs

Linkages with other FAPs are envisaged as follows:

FAP 3 - The regional scale FMM will be based on a modified version of the NCRM.

FAP 10 - The possible future use of the FMM in real time flood forecasting beyond the present phase will be investigated on a national scale and will be related to FAP 10/BWDB activities.

FAP 19 - The FMM involves the use of GIS/DEM systems which are being developed in close cooperation with FAP 19.

FAP 20 - The compartment scale FMM will be based on the Tangail study area.

9.3 Review of the Preliminary System Analysis

The original Terms of Reference for the FMM were drawn up during the Third CAT Mission. The emphasis was on the development of a FMM which would provide enhanced planning and design facilities. Following discussions between the Resident Model Co-ordinator, FPCO and PoE the TOR were amended to indicate that the long term aim was for a FMM which could be used on-line in a flood management role.

The consultant presented a paper to the FPCO, PoE in November 1992 which seeks to clarify the concept of the FMM. The FMM is described as a combination of four modules

- River Modelling Module (RMM)
- Planning and Design Module (PDM)
- Flood Forecasting Module (FFM)
- Structure Operation Module (SOM)

The CAT generally concurs with the RMM concept.

The PDM introduces GIS, the output from which is principally concerned with maps, tables and statistics. Discussions will be held with users of this information, e.g. for agriculture, fisheries, flood damage assessments, and one or two pilot exercises will be carried out by FAP 25 in close consultation with users to demonstrate the potential of PDM. The details of post-processing software for these purposes will be the responsibility of the identified co-operating users.

The FFM concerns the application of FMM to flood forecasting. Details of this latter application have not been discussed during the Fourth CAT Mission.

The SOM, as far as FAP 25 is concerned, is extend to the MIKE 11 software and represents a user-friendly interface for communicating with the structures module within MIKE 11. Any required amendments within this structures module will be referred to DHI.

In phase 2 of the project, the TOR require that tailored models are to be built as follows:

- a pilot model of the Tangail Compartment;
- a regional model of the North Central region;
- a national model, based on the SWMC General Model.

The consultants are further required to look at the possibilities of using the national model off-line for flood forecasting.

9.4 Recommendations

- The FMM project team should continue to work closely with FAP 3, FAP 10, FAP 19, FAP 20 and the SWMC;

- The FMM team should refer internal basic changes, not specifically related to FMM, in the MIKE 11 software to DHI, Denmark;

- The FMM team should actively help SWMC to adapt the NCRM such that it is more suited to the regional FMM requirements;

- The FMM team should strike a balance between the very sophisticated GIS software in use and the known limitations of the hydrodynamic data and modelling;

- The FMM team should go ahead with the proposed workshop and ensure that the views of users are fully understood. This includes people who work at regional and compartmental level;

- The FMM team should develop, as soon as possible, demonstration software so that potential users will have a better understanding of the potential of FMM.

10. COORDINATION ACTIVITIES

10.1 General Coordination

The coordination activities under FAP 25 have generally progressed satisfactory since the last visit of the CAT. As reports are now being submitted by the various FAPs, notably the regional development plans, it is the impression of the CAT that quite similar and consistent approaches are followed on modelling. A very central issue in this context has been the adaptation by other FAPs of the methodology proposed by the FHS, see Chapter 8.

Two meetings have been held in the FAP Model Coordination Committee, in May and October, 1992. Though the envisaged schedule for these meetings were quarterly, the CAT believes that the lower, actual frequency of these meetings, based on an ad-hoc assessment of their needs, have been suitable.

Three informal meetings of FAP hydro-modellers and hydrologists have been held in the last year and none since June, 1992.

Day-to-day, or ad-hoc bilateral contacts have continued to be an important coordination mechanism.

It is the opinion of the CAT that there is a continued, though decreasing, need for the model coordination as feasibility studies emerging from the regional plans are being initiated.

The CAT is in agreement with the revised coordination structure in which the day-to-day coordination will be handled by the Hydraulic Modelling Engineer. In carrying out his duties he will be supported by the Model Coordinator (the previous Resident Model Coordinator), who will have 3-4 visits a year over the next two years.

The CAT will continue its coordination role with a special responsibility for overlooking and guiding the FMM development, which is implemented as a separate contract under FAP 25.

10.2 Exchange of Models and Data Between the FAPs and GOB

Through the first three years of the FAP the procurement of data and models, and the procedures (or lack of procedures) for exchange of data and models between the GOB and the FAPs have hampered the work of many FAP studies. Several FAP studies have had to pay for data and models, though their TOR have stated that they should be provided free of costs.

However, the CAT notes that finally a solution to this highly unsatisfactory situation seems underway, not least due to the steady effort of FAP 25. Now, FPCO have funds available to reimburse FAP studies any payments they have made for model and data. FAP 25 has already been reimbursed.

Furthermore, by Government Order of November 2, 1992 a 5-men committee has been constituted with members from FPCO, WARPO and BWDB and headed by the Chief Engineer of FPCO. The Terms of Reference of the Committee are:

i) adopt procedures for exchange of data within FAP projects and fixation of uniform rates;

ii) determine the procedure for model transfer and rates;

iii) determine the procedure of exchange of data outside FAP;

iv) any other item of activities relevant to above;

The report of the Committee is due by January 1, 1993.

The CAT notes that the issue has been discussed at length in FAPMCC meetings. The CAT supports the recommendations of the Model Coordinator which would imply:

- that FAP studies, as a matter of urgency, be reimbursed for payments made for data and models;

- that FAP studies, in the need of data and models, would make a detailed request to FPCO with a copy to the concerned GOB agency;

- that FPCO, with a minimum of delay, request the concerned GOB agency to handover the requested data to the consultant;

- that any payment required for such data and models be a matter directly between FPCO and the concerned agency;

- that FAP studies, for the sake of convenience, should be allowed to collect data from other FAPs after having properly informed FPCO and the concerned GOB agency;

- that MIKE 11 software and MIKE 11 based model can only be obtained from the SWMC, and following the procedures above.

10.3 Model Updating Procedures

The CAT has reviewed the note prepared by the SWMC on model updating procedures and which has been discussed in the FAPMCC and at informal coordination meetings under FAP 25. The CAT is in general agreement with the proposed procedures.

The CAT finds that the proposed annual updating is sensible, appreciating that such updating may range from a limited verification of the model for the preceding year to a more comprehensive change in model set-up due to morphological

changes or human interventions. The CAT notes that annual verification runs are useful to detect possible errors in field data on which action may then be taken.

The proposed schedule for the annual updating,based on data for the period November through October, allows updated models, based on the latest monsoon season, to be available in due course for the forecasting in the next monsoon season. While agreeing to this in principle, the CAT foresees some problems as data are normally made available from BWDB for hydrological years, i.e. from April through March. The CAT *recommends* that SWMC approaches BWDB to address the practicalities of the proposed schedule. The SWMC should also liaise with and utilise quality data available from FAP 24.

The CAT also *recommends* that the SWMC establishes a clear nomenclature for updated releases of the General Model and the regional models.

10.4 Model Accuracy Requirements

The CAT has also reviewed the note on model accuracy requirements as discussed at the 5th FAPMCC meeting in October 1992.

The note has been prepared by FAP 25 on the basis of input from the regional FAP studies. The indicated levels of model accuracy is understood to be levels, which are acceptable for users of the model results in the various phases of project planning, feasibility and design.

The CAT find the proposed levels reasonable and realistic from a modelling point-of-view. Overall, the regional pilot stage models fulfil the accuracy requirement at planning and prefeasibility levels, though in each region there are locations where the accuracy is less. However, as stated in previous CAT reports, such major deviations may often be a result of inaccurate data and not only deficiencies in the model set-up.

The issue of possible improvement in model accuracy through a more comprehensive data collection has been brought up by members of the PoE. This issue touches upon the question of the economic value of reliable hydrological data. While appreciating the importance hereof, the CAT is not in a position, within its limited resources, to address this very complicated issue. Undoubtedly, however, the additional effort of the SWMC to improve the data collection of BWDB in 1990, 1991 and 1992 has been a worthwhile effort.

11. FUTURE CAT SCHEDULE

The CAT so far has been concerned with:

- coordination of FAP modelling activities;
- the Flood Hydrology Study;
- preparations for the Flood Management Model.

In addition, at the request of the FPCO and the PoE, the CAT has devoted considerable attention to the morphological aspects of the FAP, not only from a modelling point of view, but also more generally. These aspects are expected to continue to play an important role in the future CAT activities.

The coordination activities are now progressing well, and with the present set-up of the FAP 25 organisation adequate mechanisms are in place (Chapter 10). The CAT is expected to continue to provide overall guidance and supervision of this activity, i.e. through 1994 when the present FAP phase ends.

The Flood Hydrology Study has now been completed (Chapter 8). The continuation of this important activity should be in the form of a proper Inter-regional Study (including the Morphological Study) as recommended in Chapter 4. The CAT is prepared to assist in developing and guiding such study.

The FMM study started in mid October 1992 for a period (initially) of two years. The CAT has played a key role in defining the Terms of Reference for the FMM, and during the present Mission in discussing project concepts and plans with the newly recruited team. The continued guidance and supervision of FMM activities is now an important function of the CAT, and it is *recommended* that the future CAT Missions be planned accordingly, i.e.

- visit by one CAT Member in *February 1993* at the time of the first FMM Workshop, coinciding with review of the draft FMM Inception Report
- Fifth CAT Mission in early *October 1993*, coinciding with review of the draft First Interim FMM Report
- Sixth CAT Mission in *April 1994*, coinciding with review of the draft Second Interim FMM Report
- Last CAT Mission in *November 1994*, coinciding with review of the draft Final FMM Report

Visits by individual CAT members at critical junctures in the FAP may be required from time to time (as e.g. the proposed February 1993 visit by one member)

The CAT agrees with the request of FPCO and the PoE that future CAT Missions, to the extent possible, be scheduled to coincide with PoE meetings in Dhaka. It is hoped that the above (FMM guided) schedule will satisfy this requirement. Otherwise adjustments in the review procedure of the FMM Reports may have to made, in order that review of draft FMM reports and discussions between the PoE and the CAT can be brought to coincide.

The CAT *recommends* that the respective donors extend the contracts with the CAT members to comply with the above schedule (including provisions for possible additional visits).

Terms of Reference

for

Fourth Mission of Short-term Experts on the Coordination Advisory Team (CAT)

1. BACKGROUND

Component 25 of the Bangladesh Flood Action Plan (FAP 25), Flood Modelling and Management consists of the following three 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 Organization (FPCO), with the Danish Ministry of Foreign Affairs (DANIDA) as the lead donor. The donor agencies of France, the Netherlands and the United Kingdom also contribute to the project.

The CAT component has been ongoing since October 1990, while the FHS has recently been completed. The FMM, the last component, started on October 19, 1992. During the initial three months, the concepts and logics of the FMM will be formulated, a workshop will be arranged, and the Inception Report will be submitted.

The Team of Short-term Experts of the CAT held their first meeting in Bangldesh in October 1990, producting an Inception Report dated November 1990. The following visits of the team took place in May 1991 and December 1991. During the 3rd visit, it was decided that the fourth visit of the team should take place in September 1992, under Terms of Reference as contained in Appendix 5 of the Third Mission Report. One of the important activities of the 4th mission would be to review the initial progress of the FMM development. Due to the late start of the FMM development, the visit has been postponed to December 1992.

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;

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 specific objectives of the 4th mission include:

- advice to FPCO on necessary steps to be taken in the further coodination of modelling activities with special emphasis on model accuracy, updating and storage of models;

- review of the results of phase 3 of the Flood Hydrology Study;

- review progress of the Flood Management Model component.

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 general actions taken by the Resident Model Coordinator/Hydraulic Modelling Engineer, FPCO, SWMC and the FAP components in the light of the report of the third CAT mission, December 1991;

b) Review, in particular, the actions taken with respect to facilitating the exchange of data and model among FAPs, uniformity on data costs, charging of data and models by SWMC for FAP users, and return of data and models to GOB after FAP study completion;

c) Review the progress of model development at SWMC and proposed model updating procedures;

d) Review draft guidelines on model accuracy requirements;

e) Review the progress on modelling in the regional and other FAP studies and compliance with the modelling methodology proposed by the FHS of FAP 25;

f) Review the results of phase 3 of the Flood Hydrology Study (analysis of country-wide protection schemes) and make recommendations for updating of results from the FHS;

g) Review the progress and findings of FAP 18 Topographic Mapping - and implications for modelling;

h) Review the progress of FAP 10, FAP 19, and FAP 20 in particular with respect to their contribution to the FMM development;

i) Review the early progress of the FMM including the Consultant's proposal and discuss with the Consultant the detailed concepts and logics of the FMM;

j) Attend a meeting of the FAP Modelling Coordination Committee (FAPMCC);

k) On the basis of the above findings, make recommendations for the future coordination activities of modelling activities in the FAP by the Hydraulic Modelling Engineer, the Model Coordinator, the SWMC and the CAT. A tentative time schedule for the Team of Short-Term Experts for the remaining period of the FAP shall be prepared;

l) Report to FPCO.

4. COMPOSITION OF THE TEAM

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

- Dr. Rodney White (UK)
- Mr. Johan Grijsen (the Netherlands)
- to be nominated (France)
- Dr. Torkil Jonch-Clausen, Team Leader (Denmark)

The Team will be supported by the Hydraulic Modelling Engineer and the Model Coordinator of FAP 25 throughout their visit.

5. PROGRAMME OF THE VISIT

The team will work in Bangladesh in the period December 1-10, 1992.

Prior to leaving for Bangladesh, the Team will study available recent FAP reports of relevance for the CAT activities. The Team will work closely with FPCO and hold discussions with the relevant government agencies, FAP consultans and donor agencies.

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

6. REPORTING

The Team will submit a draft report before December 17, 1992. The final report will be submitted to FPCO, with copies to the World Bank and the donor agencies of Denmark, France, the Netherlands and the U.K. before January 15, 1993.

APPENDIX-2

Programme of the Fourth CAT Mission.

Tuesday 1 Dec	1645	CAT members arrive (One CAT member and Model Coordinator arrive earlier).
	1800	CAT Internal
Wednesday 2 Dec	0800	FAP 25
	1030	FPCO
	1200	FAP 21/22
	1430	FAP 1
Thursday 3 Dec	0900	FAP 24
	1100	FAP 6
	1300	Team Leader CAT arrives
	1500	SWMC
Friday 4 Dec		CAT Internal
Saturday 5 Dec	0900	CE Hydrology
	1030	MIWDFC
	1230	FAP 4
	1500	FAP 25
Sunday 6 Dec	0730	Danida
	0900	FAP 2
	1030	FAP 19
	1200	Mr Nurul Huda PoE
	1430	FAP 20
Monday 7 Dec	0900	FAP 3.1
	1000	DGIS
	1030	FAP 5
	1200	World Bank
	1300	Mr. Siddiqi, CE/FPCO
Tuesday 8 Dec	1030	SWMC
	1400	Danida debriefing
	1500	CAT internal
Wednesday 9 Dec	0830	FPCO Concluding meet
Thursday 10 Dec	1000	Caisse Centrale CAT Departure

List of Key Persons Consulted

MIWDFC
Mr. A.M.Khan Chowdhury, Additional Secretary
Mr. Khawaja Abdur Rahman, Deputy Secretary

FPCO
Mr. M.H. Siddiqi, Chief Engineer
Mr. A.M. Shafi, Superintending Engineer
Mr. Ashfaqui Azam, Superintending Engineer
Mr. A.K.M. Halimur Rahman, Superintending Engineer
Mr. Afzalur Rahman, Superintending Engineer
Mr. Sk. Nurul Ala, Executive Engineer

Panel of Experts
Mr. Md. Nurul Huda, Chairman
Prof. A. Hannan
Prof. Jahiruddin Chowdhury

BWDB
Mr. A.K.M. Shamsul Hoque, Chief Engineer
Mr. A.B.M. Habibullah, Director - SWH-I
Mr. Alam Mia, Director - SWH-II
Mr. Karoly Futaki, Chief Technical Adviser (BGD/88/054)

Royal Danish Embassy
Mr. K. Kjaer Nielsen, Chargé d'Affaires
Mr. P.E. Christensen, Counsellor

Caisse Centrale
Mr. Grosclaude, Technical Adviser

Royal Netherlands Embassy
Mr. Anton R.M. Schutte, Counsellor
Mrs. Bertiem de Lange, Technical Adviser

British High Commission
Dr. Harry Potter, First Secretary, Natural resources
Mr. Rodney Matthews, Engineering Advisor

World Bank
Mr. Ross Wallace, Resident FAP Coordinator

SWMC
Mr. A.S.M. Abdul Khaleque, Superintending Engineer
Dr. Ranjit Galappatti, Team Leader
Mr. Finn Hansen, Computational Hydraulic Engineer
Dr. Kim Wium-Olesen, Morphologist Modeller

FAP 1
Mr. Mike West, Team Leader
Mr. Ole Juel Jensen, Physical Modelling Specialist
Dr. K. Wium-Olesen, Morphologist

FAP 2
Mr. Tom Franks, Team Leader
Dr. Afzal Hussein, Modeller
Mr. Anwar Hussein, Hydrologist

FAP 3.1
Mr. Malcolm Wallace, Team Leader
Mr. Nayan K. Mazamder, Hydrologist/Hydraulic Modeller

FAP 4
Mr. Ram Thiagarajah, Team Leader
Mr. Tony Green, Hydraulic Engineer
Mr. Akhter Hossain, Modelling Engineer

FAP 5
Mr. Michael Pollitzer, Team Leader
Dr. Afzal Hussein, Modeller

FAP 6
Mr. Herb Wiebe, Team Leader
Mr. Larry Bodnaruk, Modelling Specialist
Mr. Mike Ibbitt, Hydrologist

FAP 19
Mr. Tim Martin, Team Leader
Dr. Thomas Chidley,
Mr. Ahmedul Hasan, Project Leader - GIS technology for MIKE 11 DEM interfacing
Mr. Iqbal Khasru,

FAP 20
Mr. Egbert Hamel, Senior Irrigation & Drainage Engineer

FAP 21/22
Mr. Hartmuth Brühl, Project Director
Mr. Maarten van der Wal, Modelling Expert

FAP 24
Mr. Pieter van Groen, Team Leader
Mr. Claus Iversen, Deputy Team Leader
Mr. Steen Asger Nielsen, Hydrologist
Mr. Palle Mikkelsen, Sr. Instrument Engineer

FAP 25
Dr. Guna Paudyal, Team Leader
Mr. Bill Syme, Computational Hydraulic Engineer
Mr. Kirk Kuykendall, Software Specialist
Mr. David Milton, FCD Engineer (II)
Mr. Fazle Rabbi, Modelling Engineer I

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APPENDIX-4

Draft Terms of Reference

for

Fifth Mission of Short-term Experts
on the Coordination Advisory Team (CAT)

1. BACKGROUND

Component 25 of the Bangladesh Flood Action Plan (FAP 25), Flood Modelling and Management consists of the following three 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 Organization (FPCO), with the Danish Ministry of Foreign Affairs (DANIDA) as the lead donor. The donor agencies of France, the Netherlands and the United Kingdom also contribute to the project.

The CAT component has been has been ongoing since October 1990, while the FHS was completed in December 1992. The FMM, the last component, started in mid October, 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 visits of the team took place in May 1991, December 1991 and December 1992. During the fourth visit, it was decided that the fifth visit of the team should take place in October 1993.

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;

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 specific objectives of the Fifth CAT Mission are:

- review draft First Interim FMM Report under FAP 25;

- review follow-up on recommendations of the Fourth CAT Mission report, notably on the key issues related to a proposed Expert Mission on River Morphology, the proposed Inter-regional Study, and harmonization of data formats, data bases and processing software;

- advice to FPCO on any necessary steps to be taken in the continued coordination of modelling activities under the FAP.

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) Liaise with FPCO and the PoE on the general progress and development of modelling activities within the FAP;

b) Attend a meeting of the FAP Modelling Coordination Committee (FAPMCC);

c) Review actions taken by FPCO, the Model Coordinator/Hydraulic Modelling Engineer, SWMC and the FAP components in the light of the report of the Fourth CAT Mission, December 1992;

d) Review recommendations made under FAP 24 and by BWDB Hydrology with respect to methods and systems for verification of new hydrological data;

e) Review, in particular, the actions taken with respect to the proposed Expert Mission on River Morphology, the proposed Inter-regional Study, and harmonization of data formats, data bases and processing software;

f) Review the general progress of the FMM including the draft First Interim FMM Report and propose any necessary adjustments for the remaining part of the FMM;

g) make recommendations on the institutional responsibility for maintenance, updating and operation of Flood Management Models considering possible developments and recommendations of FAP 26 - the Institutional Development Programme;

h) On the basis of the above findings, make recommendations for the future coordination activities of modelling activities in the FAP by the

Hydraulic Modelling Engineer, the Model Coordinator, the SWMC and the CAT;

i) Report to FPCO.

4. COMPOSITION OF THE TEAM

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

- Dr. Rodney White (the United Kingdom)
- Mr. Johan Grijsen (the Netherlands)
- Dr. Jean A Cunge (France)
- Dr. Torkil Jønch-Clausen, Team Leader (Denmark)

The Team will be supported by the Hydraulic Modelling Engineer and the Model Coordinator of FAP 25 throughout their visit.

5. PROGRAMME OF THE VISIT

The team will work in Bangladesh in the period October 1 -10, 1993.

Prior to leaving for Bangladesh, the Team will study available recent FAP reports of relevance for the CAT activities. The Team will work closely with FPCO and hold discussions with the relevant government agencies, FAP consultants and donor agencies.

The Team will present its findings to FPCO and the donors before its departure from Bangladesh.

6. REPORTING

The Team will submit a draft report before October 25, 1992. The final report will be submitted to FPCO, with copies to the World Bank and the donor agencies of Denmark, France, the Netherlands and the U.K. before December 1, 1993.

APPENDIX-5

First Draft Terms of Reference

for

Expert Mission on River Morphology

1. BACKGROUND

The disastrous floods of 1987 and 1988 prompted the Government of Bangladesh to undertake a comprehensive review of its flood policy. In June 1989, the Government of Bangladesh requested the World Bank to coordinate a five-year Action Plan (1990-95), based on earlier studies, as the first of several stages in the Government's long-term flood control program.

In its November 1989 report, the World Bank presented a Flood Action Plan (FAP), which addresses high priority problems and follows a staged approach which:

- concentrates in the first years on regional studies of flood control and drainage potential and supporting activities in order to identify feasible projects for implementation later in this and in subsequent Action Plans;

- focuses on flood control for the Brahmaputra and Ganges (with the downstream problems of the Padma and Lower Meghna deferred until the effects of upstream embankments on river morphology are evaluated).

The FAP would be carried out in a coordinated manner and in parallel with agricultural and other rural development activities and a program of non-structural measures, including flood warning and flood preparedness.

The FAP was initiated in 1990. A Flood Plan Coordination Organisation (FPCO) was set up in Dhaka and it is advised by a Panel of Experts (PoE) appointed by the World Bank. A series of Regional Studies were initiated together with a series of more generic supporting studies.

Many of the original pre-feasibility studies are completed towards the end of 1992 and one regional study (FAP 5 - in the SE region) has already moved on to the feasibility stage.

A number of specific morphological studies have been, or are being, undertaken as part of the FAP but they all have specific, non general, aims and none of these studies address the overall morphological impact of projects proposed under FAP. It is important that the overall morphological impact is assessed as soon as possible to avoid abortive feasibility and design studies which may be influenced

by changes originating from projects and proposals outside the immediate area of interact.

Morphology is a crucial environmental issue facing the FAP. Regional projects such as possible embankments along the Jamuna could cause erosion and/or accretion which will, in turn, affect water levels over a wide area. These effects may, in turn, affect ecosystems and human activities such as fisheries and agriculture.

The Coordination Advisory Team (CAT) under FAP 25 in their Third Mission Report (March 1992) and in the Fourth Mission Report (December 1992) proposed to field a mission of internationally, renowned experts in the field of river morphology to address these issues. The mission may be considered a preliminary morphological study leading to a more comprehensive study.

2. OBJECTIVES

The overall objective of the proposed Expert Mission on river morphology is:

- to write the Terms of Reference (TOR) for the morphological component of an Inter-regional Study which will look at the combined effects of regional projects and possible inter-actions between them. The Inter-regional Study has been discussed by the FAP 25 Co-ordination Advisory Team (CAT) in its third Report (March 1992) and its Fourth Report (December 1992).

Subsidiary objectives are:

- to recommend those techniques which should be used to assess morphological change caused by i) natural processes and ii) FAP projects;

- to identify those rivers which should be included in the morphological component of the Inter-regional Study, bearing in mind the nature and extent of proposed FAP projects;

- to identify deficiencies in the data available for the study and to define a programme of data acquisition, if required;

- to define the anticipated output from the morphological component of the Inter-regional Study;

- to identify mechanism, and possible adjustment of activities, to ensure proper coordination and direction of ongoing and planned morphological studies within the FAP;

3. OUTPUT

The outputs from the mission will be:

- a Mission Report with recommendations relating to:
  - * the predictive techniques to be used in the morphological component of the inter-regional study;
  - * the rivers to be investigated in the morphological component;
  - * the acquisition of further data, if required;
  - * the outputs required from the morphological component;
  - * possible adjustments in ongoing and planned morphological activities and studies within the FAP;
- Terms of Reference for the morphological component of the Inter-regional Study.

4. ACTIVITIES

The activities of the Expert Mission include:

- preparation of a literature review of documented morphological studies already carried out in Bangladesh and elsewhere;
- a review of completed and on-going morphological studies within FAP;
- a review of worldwide experiences relating natural and man-made influences to the morphology of sand bed rivers;
- a review of the techniques available for predicting morphological changes including:
  - * the use of historical data
  - * the use of field studies, including remote sensing techniques
  - * the use of computer models
  - * the use of empirical and analytic regime concepts
- liaison with regional FAP consultants with a view to identifying the nature or extent of their proposed projects;
- liaison with FPCO, BWDB, SWMC with a view to identifying the extent of sediment and morphological data available;
- preparation of a Mission Report and the Terms of Reference for the morphological component of the inter-regional study.

5. COMPOSITION OF THE EXPERT MISSION

The Expert Mission would comprise three or four internationally renowned experts in the field of river morphology and supported by local experts. The mission would provide intermittent inputs both in Bangladesh and from their home base. Approximate expatriate man-month input should be in the order of 6-10.

6. TIME SCHEDULE

The Expert Mission on River Morphology is required urgently because of on-going FAP studies which may be influenced by the findings of the morphological component of the proposed Inter-regional Study. The findings of the mission should be available by July 1993 at the latest and the members of the team would be invited to participate in the FAP 24 arranged workshop on morphology in Dhaka in August 1993.

SWMC Update Note on Morphological Modelling

SWMC MORPHOLOGICAL MODELS: BASIC APPROACH AND STATUS SUMMARY

December 5, 1992

1. INTRODUCTION

The efforts made towards developing sediment transport and morphological models at SWMC have led to achieving a broad understanding of what is possible and not possible in this particular field of modelling in Bangladesh. In addition to the inadequate quantity/quality of the available data, the constraints identified arise from the nature and complexity of the Bangladesh river systems, while others are inherent in the limitations of one-dimensional river modelling.

What is understood by a **sediment transport model** is merely the computation of sediment transport rate at all points in the river system at the required intervals of time. This computation is based on a particular sediment transport formula (a choice of four formulations are available in the current version of Mike11), the observed bed material properties and the results of a fixed bed hydrodynamic computation. No attempt is made to alter the hydrodynamic behavior based on computed changes in bed levels. In a **morphological model**, on the other hand, the sediment transport computation is done in parallel with the hydrodynamic computation, so that computed morphological changes (only the change of bed level in a one dimensional model) can be incorporated in the hydrodynamic computation from time to time.

The constraints identified have led to a reassessment of modelling strategy with respect to morphology and sediment transport. It is now recognized that "morphological" models can only be set up for relatively simple networks with a small number of branches, and that the channel topography has to be subjected to further schematization before a useful model could be built. Furthermore, the setting up of a morphological model required a deeper understanding of sediment transport phenomena, involving in many instances, additional field investigations beyond the scope of SWSMP-II. The modelling strategy, therefore, was to use the regional models only to carry out sediment transport computations, while setting up morphological models in carefully selected sub systems.

2. CONSTRAINTS

The main constraints were identified as the following:

a) Bifurcations: The split of sediment discharge at a point where the flow bifurcates cannot be predicted by any simple means. If it is at all possible to predict the split of

sediment, it would require a detailed, quantitative understanding of the three dimensional flow pattern at every bifurcation in the model. Even if a criterion was found for the split of sediment at a particular point, there is absolutely no guarantee that this criterion will remain valid for the entire duration of a typically very long morphological simulation. A morphological computation cannot be carried out if a criterion cannot be specified for the split of sediment for every bifurcation.

The presence of a bifurcation is usually tackled as a sensitivity analysis by testing a range of possible sediment split criteria, or by testing physical interventions designed to alter the sediment split. This type of analysis is practical only if one or at most two bifurcations exist in the model. The regional models have many more bifurcations than this, and in addition there are many breaches of embankments etc where uncontrolled diversions of water and sediment take place. Thus the regional models can only be used for carrying out sediment transport computations.

b) Channel Topography: Much has been written about the variability of properties which exist in the river cross sections used in the hydrodynamic models. These cross sections are a true representation of channel shapes as they existed at the time of survey. They however give a very incomplete picture of the spatial and temporal variation of channel topography. While using these cross-sections in the hydrodynamic models has been quite successful, the longitudinal variation of computed mean velocity could sometimes be very large. When such cross-sections are used in a morphological model, very large bottom level changes are predicted, which turn out not to represent the movement of **the average bed level** which is of interest to the morphological modeler. Instead the computed level changes are a kind of noise (related to bed forms and other localized features) and obscure the overall trend.

It has thus proved necessary that the river topography to be used in a morphological model be always strongly schematized to remove the noise, while retaining the essential hydraulic properties of the river(s) under study. In order to do this schematization with any degree of confidence, a good understanding of the river and its flow regime are essential.

Sediment transport computations are also adversely affected by this variation in channel properties. This can however be overcome to some extent by averaging out the total sediment transport for an entire reach of the river. Thus, it is still feasible to run the sediment transport model using the topography used in the hydrodynamic model.

3. DEVELOPMENT OF REGIONAL SEDIMENT TRANSPORT MODELS

This section describes the pure sediment transport computations which have been carried out for non-cohesive and cohesive sediment, using regional models. No sediment transport computations have so far been carried out using the General Model. However, the Jamuna-Ganges-Padma morphological model is described in section 4.

3.1 South East Region

The South East Region can be considered from a hydraulic point of view to be split into a northern and southern part by the Gumti River. The hydrodynamic model was been split into two models accordingly. This division was maintained for the initial trials of the sediment transport model. These trials revealed in some branches of the model a variability of transport unacceptably large even for sediment transport computations. This actually led to a complete reassessment of the topographic data and the setting up of a revised hydrodynamic model where the two subregional models were merged into a single South East Region Model under the unix operating system.

The first trial computation of sediment transport on the full SERM has just been completed. So far no serious morphological modelling has been undertaken. Of the several possible subsystems for which morphological models might be established, the most promising would be an investigation of the effect on the Lower Gumti of building a regulator at Jibanpur which effectively cuts off the northward spill of flood water.

3.2 South West and South Central Regions

Non-cohesive sediment transport simulations have already been carried out with the full South West Region Model. The results of the simulation of one full hydrological year proved to be difficult to handle (with the generation of two result files each of 200 Mb). However, FAP4 was able to analyse these data and gain insight into the seasonal changes in the net circulation of sediment in the region. The variability of cross sectional properties resulted in widely differing sediment transport rates at a few grid points. On a later date four simulations, were carried out for pre and post project conditions, for 28 tidal cycles each in a wet and dry month, on a slightly modified model which was more detailed in the central poldered area, again at the request of FAP4.

Initial runs with the new cohesive sediment transport module have been carried out on the full South West Region Model. The purpose of these simulations are to establish boundary conditions for sub-regional models. The first trials runs with a sub-regional model (CERP II) will be carried out during the

current input of the Morphological Modeller, and the specifications of a data collection programme (to be carried out during SWSMP-III as well as by the CERP-II Consultants) will be worked out.

The attempt to set up a morphological model of the Gorai river will be described in Section 4.

3.3 North West Region Model

Sediment transport computations have been made with the Atrai Basin Model and with less success on the Teesta Project Drainage Model. There has been some difficulty in reconciling the results of the analysis of channel geometry and the actual sediment movements calculated because of several large breaches of embankments which do not appear to be annual occurrences. The results obtained with the final version of the full hydrodynamic model exhibit much less longitudinal variation when compared with the Pilot Model.

3.4 North Central and North East Region Models

Only preliminary sediment transport computations have been carried out on these two pilot models. Further modelling work is being undertaken. There are distinct possibilities of setting up morphological models for the Khowai River as well as for the Kushiyara-Kalni River of the North East Region, where significant morphological changes have occurred in the past few decades.

4. DEVELOPMENT OF MORPHOLOGICAL MODELS

This section describes the morphological simulations which have been carried out so far. Setting up morphological models has turned out to be very time consuming and requiring a large number of data. This is because the sediment carrying capacity of the river branches in the models which are based on surveyed cross-sections are highly non-uniform. This variability is mainly due to bed features which are local in nature, but probably also caused by inaccuracies in the cross-section data (eg. bench mark errors). Extensive analysis of cross-sectional data is therefore required in order to smooth out the "random" variability before the models can be used to simulate general changes and trends in bed levels.

4.1 General Model

A very large number of cross-sections from the Jamuna, Ganges and Padma have been analyzed, and smoothed cross-sections have been developed, so that they have the same average hydraulic properties as the natural rivers. A simplified Jamuna-Ganges-

Padma Model (JGP Model) has been developed using these artificial cross-sections, and calibrated successfully against observed water levels and discharges, using reasonable parameter values.

With a constant calibration factor the morphological model reproduced the observed sediment rating curves at Bahadurabad, Baruria and Hardinge Bridge as well as the observed constriction scour at Hardinge Bridge.

A morphological study was carried out in collaboration with BRTS (FAP 1), in which the following scenarios were investigated:

1) Effect of narrowing the width of the Jamuna to 4000 m, 5000 m and 6000 m

2) Construction of the Jamuna Bridge

3) Construction of the Jamuna Left Embankment

4) Sea level rise of 0.5 m

5) Increased sediment load (+ 50 %) in the Jamuna river.

4.2 South West Region

The Gorai-Madhumati Model has been established and are currently being calibrated. The model is based on idealized cross-sections which have been established in the same way as the cross-sections used in the JGP-Model. Analysis of a large number of cross-sections reveals a distinct variation of the longitudinal slope of the river, which only can be explained by either large spills from the river, longitudinal variation of the width of the river or by longitudinal grain size variation.

Discharge records at Gorai Rail Way Bridge and at Kamarkhali suggest spilling between these stations, but the slope variation in the Gorai suggests the opposite. The width seems to be larger in the vicinity of the Ganges off-take, which is consistent with the observed slope variation, but no apparent reason for the increased width in this area has yet been identified. Data on bed sediment grain sizes are insufficient to document any longitudinal gradient in bed sediment size. The issue is being further investigated.