FAP 25: Flood Modelling and Management

Flood Management Model

Interim Report - II

July 1994

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6

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

1.1 Project Outline

The FAP25 - Flood Management Model, (FMM), component commenced in October 1992 and is planned to continue until October 1994. The overall objective of the FMM is to provide a tool which, through prediction and analysis of the behaviour of floods, assists in the management of mitigation measures to minimize flood damage.

The FMM study is being carried out in two stages. The main activity of Stage 1, the Development Phase, was to develop the MIKE11-GIS interface which will permit improved river and flood plain modelling and the generation of flood maps. Stage 2, the application Phase, concentrates on the development of dedicated FMMs at national, regional and compartment levels. The activities related to FMM development are largely complete and those related to application are in progress. A proposal has been prepared for the institutionalization of FMM after the end of the project.

1.2 The Second Interim Report

The Terms of Reference for the FMM project require a Second Interim Report to be submitted together with an Interim FMM User's Guide. Since the draft Reference Manual has already been submitted and it is planned to deliver the First Draft Final Report by the end of July 1994, this report (Interim Report-II) has been prepared mainly to report the status of work progress during January to April 1994. A Training Manual in the form of a tutorial guide will be submitted with the final report. The Training Manual will ultimately be used as a training material, and as a procedural guide for trained users.

The general progress of the ongoing activities is described in Chapter 2 together with the revised schedule of future activities.

Chapter 3 presents the FMM development update describing a few additional features and revisions which were implemented based on feedback received from in-house users during the application.

The consolidated comments to the Draft Interim Report-II and the replies and presented in Appendix-A.

Chapter 4 presents the status of the activities related to the development of the dedicated North Central Regional (NCRM) FMM. The calibration of the restructured NRCM is presented and flood maps are produced which compare flooding characteristics obtained from the restructured NCRM with those from the basic SWMC model.

Chapter 5 presents the Tangail Compartmental FMM. The updated Tangail model is presented together with flood maps produced as an activity of the FMM application.

1.3 Documentation

The following documents have been prepared by the project:

- FAP25 - Flood Management Model: Inception Report, April 1993.

9

- FAP25 25 - Flood Management Model: Interim Report - I, January 1994.
- MIKE11-GIS Reference Manual (Draft), November 1993.
- MIKE11-NAM Dynamic Interface, November 1993.
- Training Manual July 1994 (to be submitted with the Final Report).
- FAP25 - Flood Management Model, Draft Interim Report - II, April 1994.

The following documents are technical references relevant to the present work:

- MIKE11 Reference Manual, DHI, 1993.
- MIKE11, Users Guide, DHI, 1993.
- ARC/INFO Manuals and Documentation.

2. WORK PROGRESS

2.1 Progress and Revision of Activities and Schedules

The activities of the project are progressing according to the revised Work Program submitted with the First Interim Report in January 1994. The FMM development activities are largely complete. Some of the features of the MIKE11-GIS interface were revised based on user feedback during the initial application period. The development tools are now being rigorously tested in the application environment.

The work on the application of FMM on the national scale (GM-FMM) has been started with the transfer of the model from SWMC and the acquisition of the national level DEM. However, as planned, in this case no revisions will be made to the MIKE11 model structure. Updating the model database for the 1993 flood season has been completed and long period runs commenced for provision of boundary conditions for the regional model. Application of GM-FMM in flood forecasting will be coordinated with the BWDB Flood Forecasting and Warning Centre and trial runs will be carried out during the coming monsoon.

The DEM for the North Central Region, (western part), has been obtained from FAP-19 and incorporated into the database of MIKE11-GIS. Regional scale applications, based on the North Central Region, depend on the restructuring of the basic SWMC model. This has been completed with some improvements made to the original calibration. The form and content of the demonstration runs have been discussed among FPCO, donors and the project team and work is in hand to set up and run these demonstrations.

The development of the Tangail Compartmental FMM has been completed. Applications are being carried out. The details are presented in Chapter 5.

Activities related to knowledge transfer through demonstration and on-the-job training have continued with growing interest from FAP consultants to use the FMM technology in their studies. FAP25 has been providing expert advice to consultants on the application of and data needs for FMM to be used in the new feasibility study projects in the North Central Region (e.g. FAP 3.1 and 3.2)

The principle that the Surface Water Modelling Centre should host the FMM after the conclusion of FAP25 has already been established. A proposal has been submitted to FPCO which details the manner in which this could take place.

Figure 2.1 shows the revised schedule of the main project activities. Activity number 750, Training, while not included in this project, has been identified here to show the future requirements for handover to SWMC. Figures 2.2 and 2.3 present the expatriate and local staff schedules, respectively

2.2 Future Activities

Having completed stage 1 of the TOR, the Development phase, the activities of stage 2, the Application phase are described below:

a) Finalisation of General FMM Development:

- Except for small modifications and dubugging as the need arises, no more time will be devoted to general FMM development.

- The software development tasks pending in January 1994 (see Interim Report I) have been completed, except for task (c): "embankment breaching, on-line operations and optimisation methods. Embankment breaching is only of concern to MIKE11, while the two other issues have been recommended by the CAT mission to be dropped.

- The MIKE11 GIS Reference Manual will be completed soon and combined with a user's Gide. The draft workbook will be completed and renamed as Training Manual.

b) Bespoke compartment FMM:

The Tangail Compartmental FMM will be tested in evaluating plans, designs and structure operation options. Outputs in the form of flood maps, duration maps, flooded area statistics, difference maps etc., will be provided for further analysis by sector specialists.

c) Bespoke Regional (NCR) FMM:

Activities related to the application of the NCR-FMM, as described in Chapter 4, will focus on demonstrating the applicability of FMM in a regional context. However, guidelines will be prepared for future area-specific model development and application.

d) Bespoke General FMM:

According to the TOR, the demonstration of FMM application at the national level will be based on the General Model (GM) developed by SWMC. The main task stipulated for the GM-FMM is to test in collaboration with FAP10 real time inundation forecasting and to provide FAP10 wil the national DEM and the developed MIKE11-GIS interface. Given the rough schematization of flood plains in the GM, it remains to be assessed to what extent the GM-FMM can produce useful results. FAP10 has not started yet, but contacts have been made with BWDB FF&WC for collaboration during the coming monsoon. It is proposed to use the output from the FF version of GM during real-time forecasting and to prepare inundation maps. The approach to modelling in FAP10 has been revised by the DANIDA appraisal mission. The modelling activities including area inundation mapping for selected pilot areas will now be carried out at SWMC. Since all the FMM activities including the MIKE11-GIS interface will be handed over to SWMC, FAP10 will be able to continue to apply the tool in its project.

Project: FMM

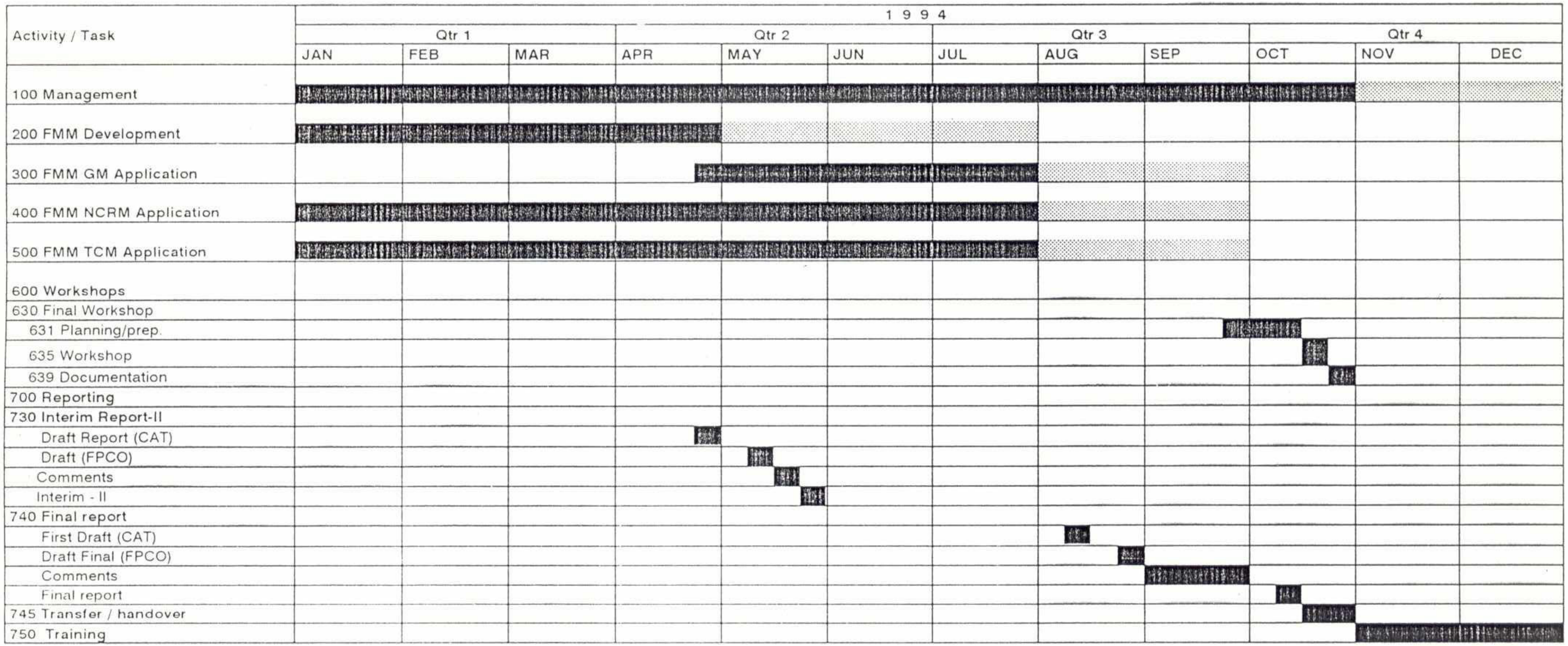
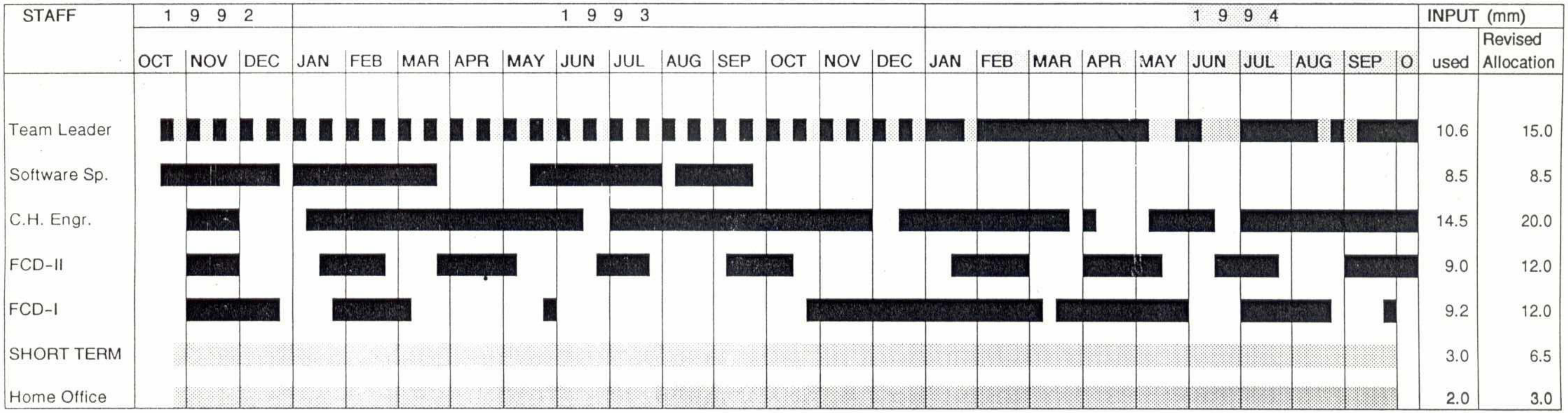


Figure 2.1: Work Program for 1994

20

DATE ==> 30/ 04/ 94

EXPATRIATE STAFF INPUT



Full Time Input

Part Time Input

Figure 2.2: Schedule of Expat. Staff Input

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LOCAL STAFF INPUT

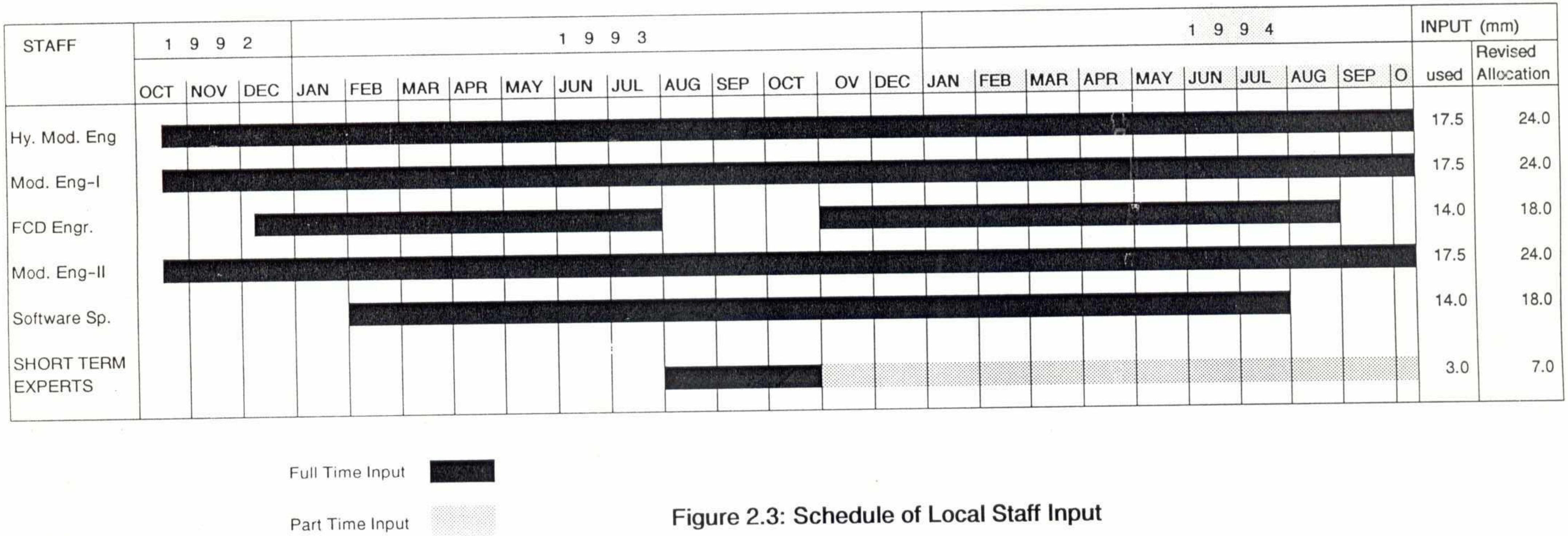


Figure 2.3: Schedule of Local Staff Input

GNP: Guna Paudyal, TL (DHI)

3. FMM DEVELOPMENT UPDATE

3.1 Summary

FMM development has continued based on feedback from in-house users during the initial application phase. The feedback has been very positive and helped to fine-tune and polish the developed software.

The future development needs documented in the First Interim Report have been implemented and are briefly described in the following sections. The menu design and structure of the MIKE11-GIS user interface has been reviewed, redesigned and modified based on user feedback. Overall MIKE11-GIS is more functional and practical than several months earlier, thus highlighting the need to incorporate rigorous application into the development process.

The quasi 2-D (FP4) approach to modelling floodplains in the North Central Region has also provided valuable feedback. The main consequence has been the implementation of an easier and more efficient methodology for modelling flows between river and floodplain.

A workbook for MIKE11-GIS is submitted with this report. The workbook will be ultimately be used for teaching MIKE11-GIS and as procedural reference for trained and experienced users.

3.2 MIKE11-GIS User Interface

3.2.1 Menus

Based on application feedback most of the MIKE11-GIS menus have been modified to some extent, with some menus being totally redesigned. The end result has been a more user friendly and functional system.

It is not expected that there will be many more changes during the remaining application phase. The MIKE11-GIS Reference Manual will be updated and edited to reflect the menu changes. The updated manual will be submitted with the Final Report in July/August 1994.

3.2.2 DEM Shading

Shading of the DEM for background display can now be controlled by the user. Previously the DEM was grey shaded based on its lowest and highest elevations. Now the user can specify the lowest and highest elevations and the shading colours. This facility has proved very useful for visualising and inspecting floodplain elevations whilst editing coverages and extracting cross-section profiles.

3.3 Data Exchange

Transfer of MIKE11 data to MIKE11-GIS can now be made using binary formats. Previously only ASCII or text files were used (except for water levels and discharges). This facility has enhanced the speed of data transfer of MIKE11 model data and simulation results. MIKE11 cross-section databases can also be transferred in binary format.

Another more significant enhancement is the use of a common "index" file for allocating unique IDs to MIKE11 branch names. This file was previously only managed by MIKE11-GIS, but because of ARC/INFO's slowness in allocating IDs to imported MIKE11 branches, an alternative method was needed. A common index file accessible to both MIKE11 and MIKE11-GIS is now used. Both programs can update and allocate IDs using the file, greatly decreasing the time for importing MIKE11 data. The time saving is primarily because MIKE11 can now output files directly in ARC/INFO binary formats without any need for ARC/INFO to modify the files or allocate branch IDs.

3.4 DEM Cross-Section Profiles

3.4.1 Viewing and Editing DEM Profiles

Viewing DEM profiles has been enhanced by including zoom functions and sections of profiles can also be deleted to remove unwanted data. The general viewing environment has also been enhanced with control over DEM shading and the display of MIKE11-GIS coverages in the background.

3.4.2 Merging Cross-Section Profiles

A new MIKE11-GIS facility was developed to merge DEM cross-section profiles with surveyed river profiles. DEM profiles describe the floodplain while surveyed profiles may only describe the river. Where river and floodplain were to be modelled as one profile, problems arose because there was no easy way of merging a surveyed river profile and a DEM floodplain profile.

MIKE11 was modified to export a cross-section database to MIKE11-GIS in binary or text format. MIKE11-GIS imports the profiles and can merge a selected profile with a DEM profile. The merging process is performed graphically, allowing the user to visualise the merged profile. Datum differences and variations in relative resistance between river and floodplain are also catered for. The merged profile can also be edited if necessary. Exporting merged profiles to MIKE11 is carried out in the same way as for DEM profiles.

3.5 Modelling Floodplains

3.5.1 Quasi 2-D (FP4) Schematisation

Adapting the North Central Region (NCR) Model to a quasi 2-D (FP4) model is seen as an important and necessary step towards accurate flood mapping. In addition to the existing river branches, floodplain branches and floodplain cells were needed together with branches linking the rivers and floodplains (spill channels) to model overbank flows and khals.

Floodplain branches were identified as long stretches of floodplain where the flood level would not be horizontal but would have a slope. These branches would be modelled as a series of floodplain DEM profiles (as a river branch), with spill channels connecting at either end and at intermediate points along the branch.

Floodplain cells were identified as areas of floodplain where the flood level would essentially be horizontal and act as a storage pond. One or more spill channels would connect the floodplain cell with the river(s).

Spill channels were to be modelled as either a broad-crested weir or a long weir (includes bed friction and slope) using an "open culvert". The broad-crested weir is more suitable for man-made embankments, while the long weir approach is more appropriate for natural river levees.

Several concerns were voiced regarding the spill channels. For example, it was estimated that approximately 100 spill channels would be needed which would require:

(a) 100 additional branches to the 51 river branches and 11 floodplain branches.
(b) 200 "dummy" cross-sections (MIKE11 requires a cross-section immediately upstream and downstream of a structure such as a broad-crested weir or culvert). These cross-sections are referred to as dummy cross-sections because they are typically entered as having "infinite" (very large) cross-section area. Cross-section profiles either side of a structure are used to modify the inlet and outlet head loss coefficients according to the ratio of their flow area with the structure flow area. In the case of a spill channel, this is not necessary, hence the use of dummy profiles with infinite area.

3.5.2 Link Structures

To help model spill structures more easily and efficiently the link sructure feature was introduced. Link structure features are:

(a) All information is entered on one menu. The required information consists of the link structure's name; upstream and downstream chainage; connections to river/floodplain branches; Manning's n or M and head loss coefficients; upstream and downstream bed levels; and a depth/width table.
(b) "Dummy" cross-section profiles upstream and downstream are <u>not</u> required.
(c) Storage (flooded area vs elevation data) can be assigned to one end of a link structure to model floodplain cells.
(d) Link structure can be assigned the same name as a river or floodplain branch (typically the start and end of a floodplain branch).
(e) Link structure appear in longitudinal profile plots of river and/or floodplain branches.

Link structure can be used to model both overbank and khal flows. This can done as a combined section by using a "slot" to model the khal. Alternatively, two link structures, one for overbank and one for the khal (or several khals lumped together) can be used.

Application of link structures to the NCR Model significantly reduced the difficulty in setting up a quasi 2-D representation. Management of the model has also proven to be easier and more efficient than would be using earlier techniques.

3.5.3 Floodplain Cell AE Curve

The MIKE11-GIS flooded area vs elevation (AE) curve computation from a DEM has been adapted to comply with floodplain cells. AE curves can be exported to a MIKE11 cross-section database without having a link to an existing MIKE11 cross-section profile. The AE curve is placed in an empty processed data table with elevation and additional flooded area data only. The river name and chainage is assigned by the user in MIKE11-GIS and the DEM is used for the TOPO-ID.

3.6 Water Surface Coverage (WSC)

3.6.1 Digitising Water Level Lines (WLL)

WLLs in a WSC previously had to be digitised so that their mid-point lies near a branch route. This was a significant limitation, especially if the branch route was re-calibrated. A new method has been developed which now has no restriction on the method used for digitising WLLs, (see Reference Manual).

3.6.2 Water Level Cells (WLC)

To represent floodplain cells in a WSC as a horizontal pool of water was previously not possible. A new feature in WSCs, named water level cells (WLC) has been included. WLCs are polygons which define a cell of horizontal water level. They are digitised in a WSC using a similar procedure to storage cells in a storage cell coverage.

3.7 Flood Mapping

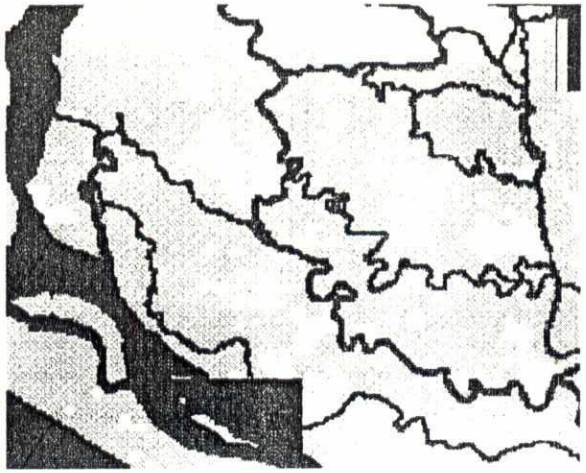
3.7.1 Flood Duration Mapping

A method has been tested which facilitates the production of flood duration maps from simulation data. The method allows the user to consider periods of analysis ranging from 7 to 30 days, together with the option of examining various flood duration periods. Table 3.1 shows a typical set of parameters used in the duration mapping:

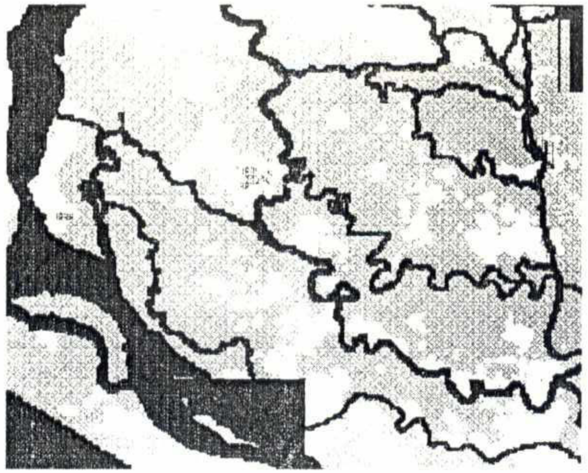
Table 3.1 Parameters Used for Flood Duration Mapping

Parameter	Range	Typical Value
Start Time	any	1 June 1993
End Time	any	31 July 1993
Interval	7, 10, 15, 30 days	10 days (decade)
Critical Duration	2 to 10 days	4 days

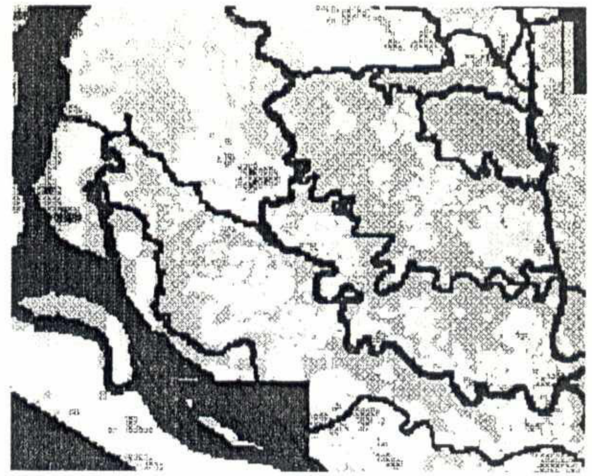
Figure 3.1 shows an example of flood duration mapping based on the typical parameters , (right-hand column), of Table 3.1. The area selected is a part of the North Central Region. These maps show the maximum areas inundated for a period of 4 days, within each 10-day period considered. Since the period chosen, (from June 1st to July 31st), represents a period of rising water levels, inundation areas are shown to increase. Choosing a period later in the season could equally well show reducing areas of inundation.



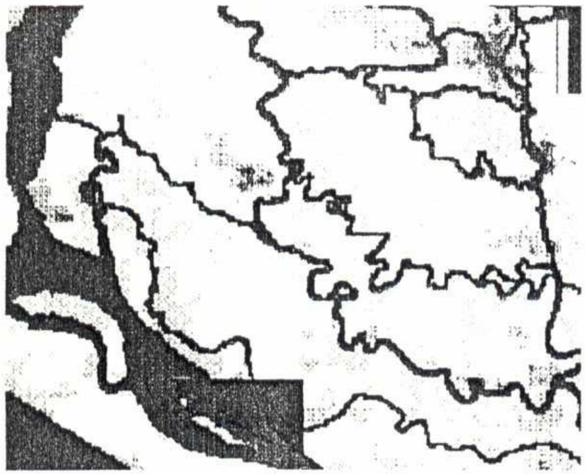
Decade 1



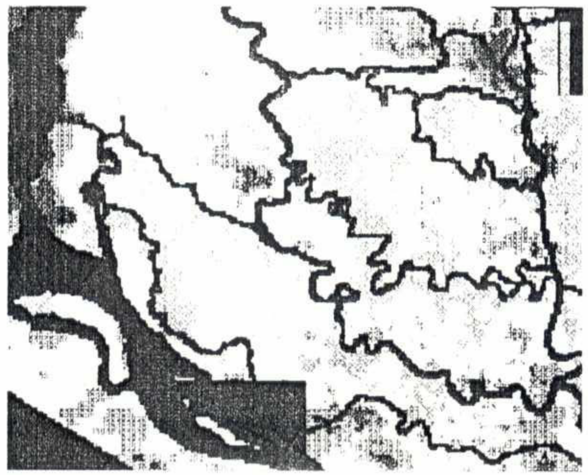
Decade 2



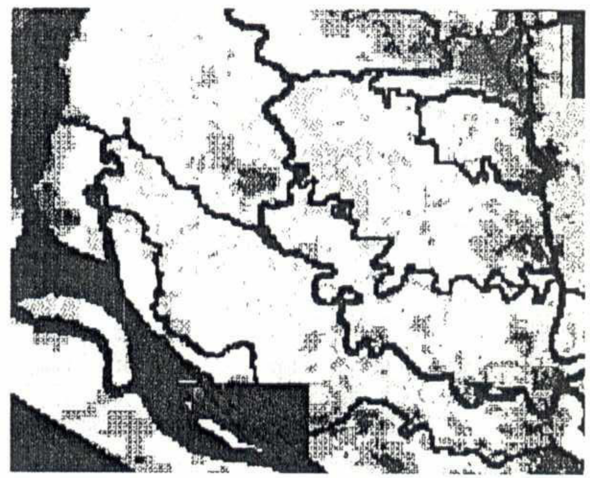
Decade 3



Decade 4



Decade 5



Decade 6

A Typical Flood Duration Map

3.7.2 *Flood Damage Mapping*

There are many ways by which flood damage mapping may be done. The flood maps and duration maps will form a basis for flood damage mapping by sector specialists. In computing flood damage to crops, the duration maps become very useful. A typical exercise was carried out to show flood damage mapping by considering critical flood depths for a crop. The value of the critical depth changes with the crop growth stage (Figure 3.2). A flood damage map for the same area as shown in Figure 3.1 is shown in Figure 3.3 using the critical depth concept as used by the FAP5 - South East Regional Study (Ref. 8). According to this method, in each decade (with three decades per calendar month), crop failure occurs on the fourth day on which the depth exceeds the critical value. Each decade is represented as the maximum of a running four day minimum level, starting by looking three days backwards into the previous decade.

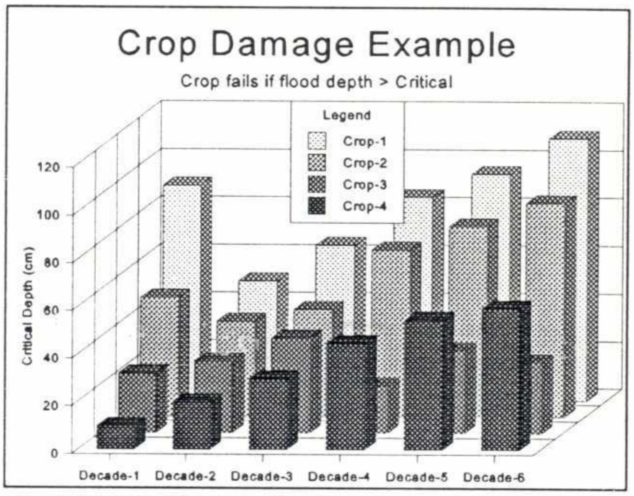


Figure 3.2 Critical Depths for Crop Damage

In produce the damage map, the flood depth map for each decade was superimposed with the crop coverage and the critical depth was used as a classification criteria.

3.8 Statistics

Flooded area statistics for a selected area can be produced in tabular form. The selected areas are either digitized on-screen over a flood map or can be pre-edited and saved as a polygon coverage. Flooded area statistics can thus be produced for planning units, upazilas or for a variety of land use coverages, e.g agricultural, urban, rural etc.

The MPO flood phases are used for defining the flood depth classes. Figure 3.4 shows an example output of flooded area statistics. The flooded area statistics for two hypothetical units defined as compartments in the North Central Region are produced as tables accompanying the flood map. Also shown in the figure are pie charts of the flood depth classes. An experienced user can analyse the tables and produce a graphic output as desired. The tables can be exported as data to any form for further analysis.

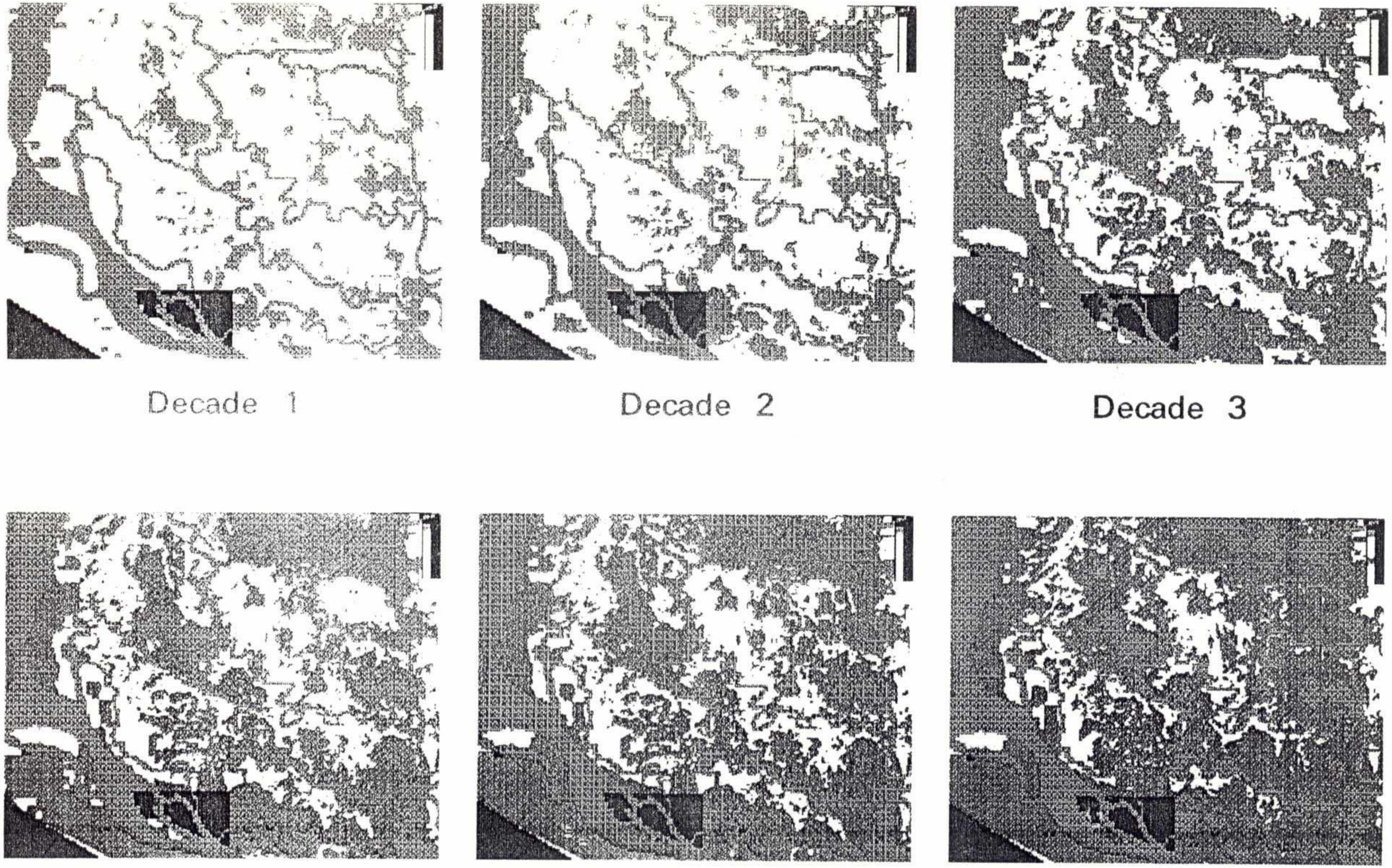
3.9 MIKE11-GIS Workbook

A draft of the MIKE11-GIS Workbook has been prepared and is submitted with this report.

The workbook presents a series of tutorials covering different aspects of using MIKE11-GIS for developing flood models and for producing output such as flood maps. It has been designed to be used as both training material and as a procedural guide for trained and experienced users.

The workbook assumes the trainee or user is experienced in the use of MIKE11, but has no GIS experience.

Figure 3.3

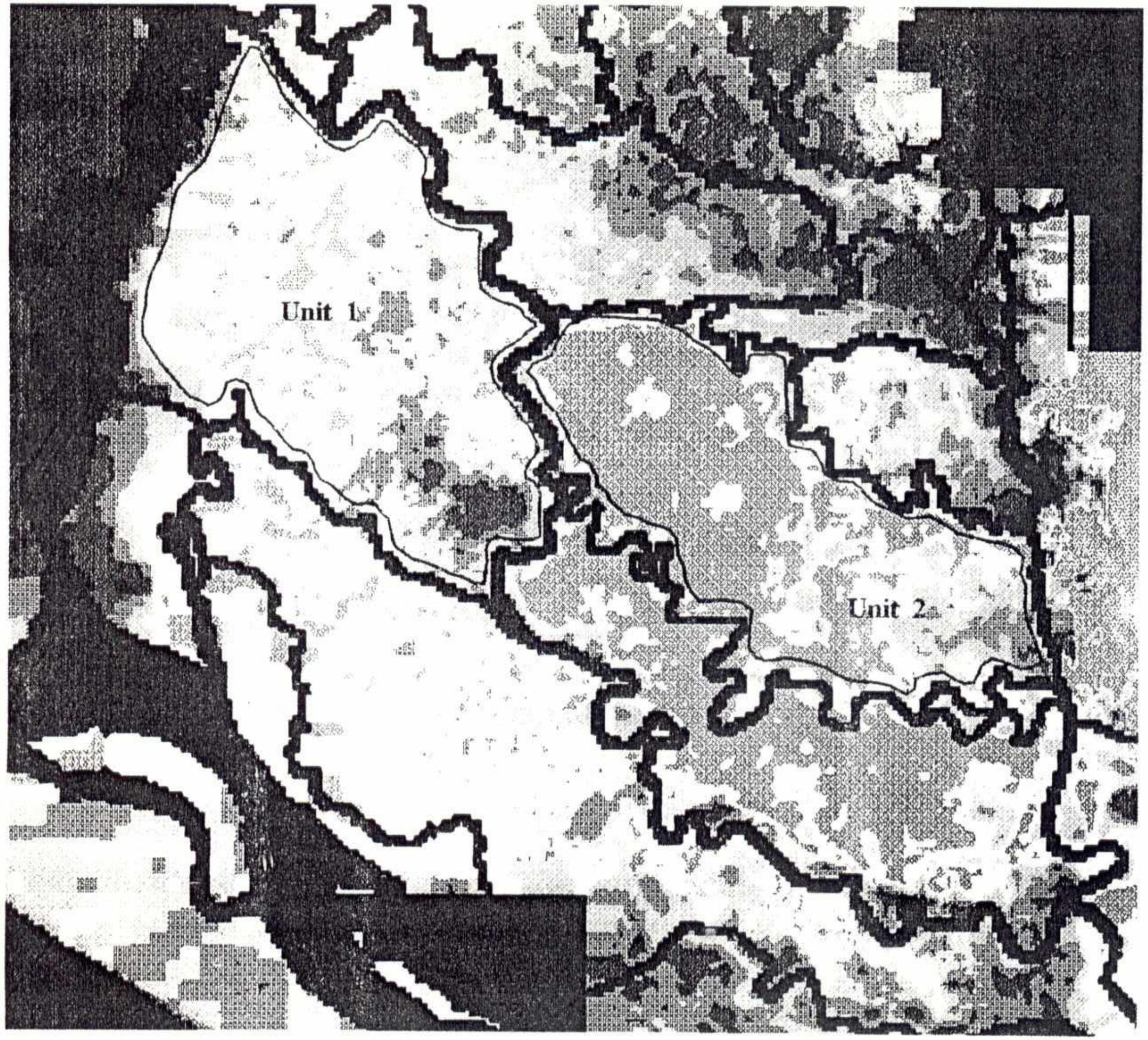


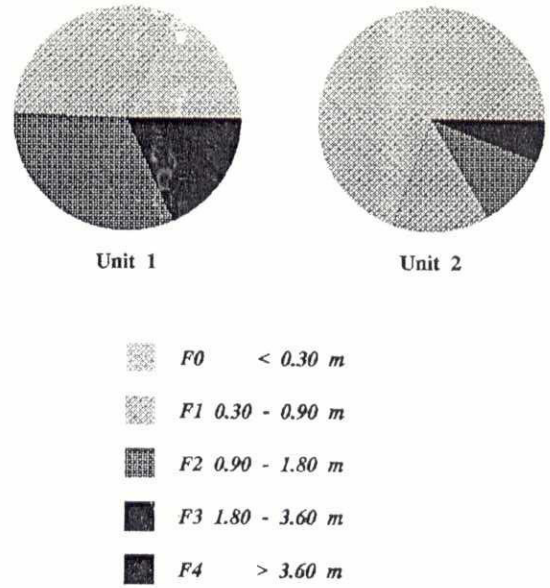
Decade 1 Decade 2 Decade 3

Decade 4 Decade 5 Decade 6

An Example of Crop Damage Mapping

Figure 3.4





Area: Unit 1			
Maximum Depth	= 7.00 m		
Mean Depth	= 1.08 m		
Total Area	= 376.53	sq.km	
F0 (< 0.30 m)	= 68.91	sq.km	(18.30%)
F1 (0.30 - 0.90 m)	= 117.18	sq.km	(31.12%)
F2 (0.90 - 1.80 m)	= 121.41	sq.km	(32.24%)
F3 (1.80 - 3.60 m)	= 63.52	sq.km	(16.87%)
F4 (> 3.60 m)	= 5.51	sq.km	(1.46%)
Area: Unit 2			
Maximum Depth	= 7.69 m		
Mean Depth	= 0.37 m		
Total Area	= 292.31	sq.km	
F0 (< 0.30 m)	= 203.18	sq.km	(69.51%)
F1 (0.30 - 0.90 m)	= 40.38	sq.km	(13.81%)
F2 (0.90 - 1.80 m)	= 31.49	sq.km	(10.77%)
F3 (1.80 - 3.60 m)	= 17.13	sq.km	(5.86%)
F4 (> 3.60 m)	= 0.13	sq.km	(0.04%)

Flooded Area Statistics

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4. NCR FMM APPLICATION

4.1 Introduction

The previous Interim Report No. 1, (issued January, 1994), presented model application progress which, at that time, was taking place parallel to the development of the MIKE11-GIS software tools. A test area within the North Central Region, called the Manikganj area, was set up to provide preliminary indications of methodology appropriate for quasi 2-dimensional model setups. Since the Report was issued, work has proceeded on the definition of a quasi 2-dimensional setup for the western part of the North Central Regional Model.

At the time of compilation of this Interim Report, the required restructuring of the NCRM, as received from SWMC, has now been completed. This Chapter of the Interim Report describes the progress of work to date and briefly explains the methodology used. Detailed methodology will be described in the Final Report, scheduled for presentation in draft form at the end of August, 1994.

4.2 North Central Model Restructuring

4.2.1 The Basic Model

The restructuring of the NCRM was based on the model received from the Surface Water Modelling Centre. This basic model is fully described in the SWMC report, "North Central Regional Model, Full Calibration and Verification Report", December, 1993, (Ref.9).

While the SWMC model adequately describes water level and discharge characteristics within the river network, it was not designed to provide such information in situations where river and flood plain water levels may differ. Such are the cases in a significant proportion of the western part of the North Central Region where adjacent flood plains are at a lower elevation than the peripheral river banks.

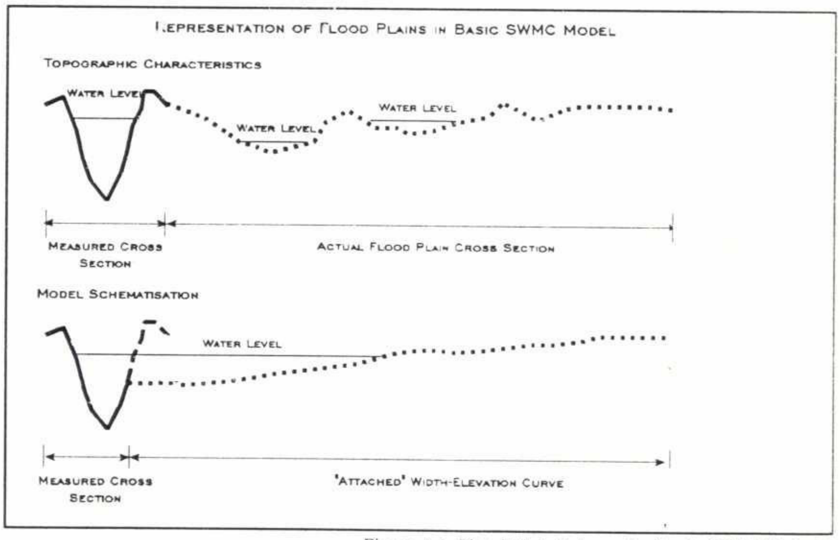


Figure 4.1 Flood Plain Schematisation in SWMC Model

It is not correct to infer from the above that the basic model does not consider the flood plains in any way. The model incorporates the storage and discharge characteristics of adjacent sections of the flood plain by "attaching" area-elevation curves to the appropriate river cross-section. While this method accounts for the storage effect of the adjacent flood plain, it cannot account for the possible difference in water level between river and flood plain. In addition, the integrated area-elevation curve does not consider the physical distribution of the topographic variation and hence the SWMC model is not appropriate for the purposes of FMM in the North

Central Region. Figure 4.1 illustrates this situation, typically found in the south-western part of the North Central Region. The lower average width-elevation curve is derived from the calculated area-elevation curve by dividing the flood plain area by distance between cross-sections.

The structural shortcomings of the SWMC model relate solely to the needs of the FMM for the North Central Region to consider flood plains as separate entities. The justification for this may be observed each monsoon season in the south-west of the region particularly, where, although river water levels may fluctuate considerably, only relatively minor flood plain water level fluctuations are observed. In addition, separation of river and flood plain permits the effect of direct rainfall on the flood plain to be evaluated - an important point when considering the compartmentalisation concept.

It is therefore clear from the above, that a basic pre-requisite for the NCR FMM is the development of a re-structured MIKE11 hydrodynamic model which is capable of addressing the particular needs of flood plain modelling.

4.2.2 FMM Floodplain Representation

Flood plains in the NCR FMM have been schematised in three ways, according to the physical description of the relevant area. Areas where topographic features, (identified from photographic images, DEM or local knowledge), indicate that water is stored on the flood plain are schematised as discrete flood cells. Where the flood plain exhibits significant slope along the approximate direction of probable flow, and there is no significant impediment to flow, flood plain branches have been inserted. In some areas, particularly those where little topographic information is presently available, have been left essentially unchanged from the schematisation in the basic SWMC model.

The present NCR FMM consists of 11 flood plain branches and 11 flood storage cells. The rivers Turag, Tongi Khal and part of the Lakhya are treated as in the SWMC model, either because the topography does not justify quasi 2-dimensional structures, or through lack of topographic data to enable realistic modification to be attempted.

Another major difference between the NCR FMM and the SWMC model is in the incorporation of parts of the Jamuna, Padma, Meghna and Arial Khan rivers in the former model. There are two reasons for this as follows:-

- In order to represent the effect of exceptionally high boundary river water levels on the flooding of adjacent land, additional high-level linkages are required between these rivers and adjacent internal rivers.
- It is anticipated that runs consisting of long time series will be required and the inclusion of the boundary rivers will reduce the number of boundary time series files needed.

Flood plain branches have been incorporated in exactly the same way as river branches. Cross sections of the flood plain are used in the MIKE11 hydrodynamic model to determine water levels and discharges at h- and q-points, in the same way as they are determined in river branches.

Flood cells, having no conveyance properties, require no cross sections, but are assigned area-elevation curves. The water level that prevails in the cell is determined from the h-point attached to the "downstream" end of one of the link structures from an adjacent river section, (see Figure 4.2).

Even if more that one link structure is connected to the flood cell, the water level at the "downstream" end of each will be the same, (since it is a node in the model).

4.2.3 Linkages

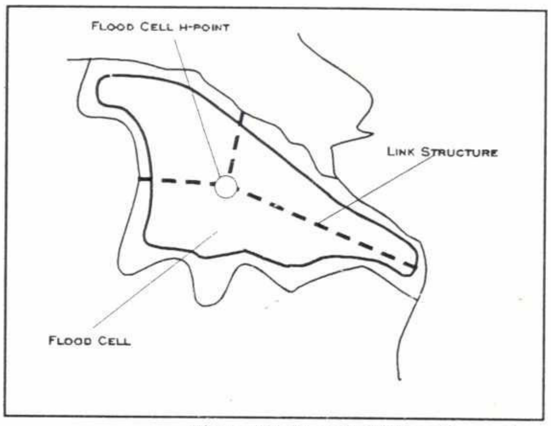


Figure 4.2 Flood Cell / River Connections

One of the most important components of the NCR FMM, and one which has probably the most influence on its representativeness, is the schematisation of the river / flood plain interaction. At a regional level of modelling, it cannot be expected that the MIKE11 model would incorporate each and every spill point or khal intersection. It has been necessary to adopt a "lumped" representation, in order to keep the complexity of the model at a workable level.
The mechanism of flood plain inundation in the North Central Region can take a number of forms, which may occur independently, or simultaneously in a number of possible combinations. The simplest causal effect is that of direct rainfall excess on the flood plain. Depending on its time of occurrence and spacial distribution, this can either fill local depressions or exacerbate existing flooding.

River water enters the flood plain initially via the network of khals that permeate the region. Since these khals have relatively low storage and conveyance properties, ingress of water from the river at rising stages rapidly causes them to fill and spill water into the flood plain. At these stages, the khal inlets from the regional rivers act as throttles to the flow into the flood plain.

The final stage of inundation takes place through low spots on the river banks or artificial levees. In some cases, through so-called "public cuts" in the embankments. In extreme cases, the embankment is overtopped extensively, often resulting in embankment failure, with catastrophic results.

The NCR FMM setup has incorporated these causes of flooding in the following ways:-

1. Rainfall Flooding

Except in cases where the original flood plain setup from the SWMC model has been used, NAM inflows have been re-directed to either flood plain branches or to flood cells. Rainfall then initially contributes to the flood plain and only reaches the river when sufficient inundation has occurred to cause flood plain water levels to be higher than those in the river.

2. Flooding from Khals

In the absence of detailed khal cross-section survey, (which would only sensibly be needed for sub-regional models), khals have been represented as open culverts, with flow possible in either direction. The sizes of these culverts have been determined by inspection of the embankment surveys made in 1993, although numerous khals into the same river have been "lumped" for the sake of simplicity. Where no data exists, a nominal representation was made.

28

3. Overbank Flooding

For this phenomenon, extensive use was made of the specially designed link structures, (see Chapter 3). These are essentially long sloping weirs, which were considered to represent flow over natural levees than the normally used broad-crested weirs. Their dimensions were established from the embankment surveys carried out during 1993, or, if no survey data was available, from a long profile along the bank line of the rivers using the DEM information. The NCR FMM consists of 89 such structures connecting rivers to floodplain branches and flood cells.

4.2.4 *Use of MIKE11-GIS*

MIKE11-GIS is a two-way tool. That is, it both receives data from and supplies data to MIKE11. Its primary output to MIKE11 is in the form of area-elevation curves of flood cells, supplemented by flood plain cross-section profiles for flood plain branches.

The NCR FMM has been restructured using topographic information from the DEM which assisted in the identification of appropriate descriptions of areas of flood plains. Extraction and display of profiles of the flood plain identified discrete areas of flood plain storage, with no identifiable flow paths. These areas were delineated as flood cells in the model, connected to adjacent rivers by link structure and open culverts to represent flow interchange.

In areas where little or no lateral impediment to flow was indicated, flood plain branches were inserted, cross-sections of these branches being abstracted from the DEM and exported into MIKE11 for use in the hydrodynamic calculations. Thus the flood plain branches were treated in the model in exactly the same way as normal river branches, but with suitable increases in the resistance factors for these flow pathways.

4.2.5 *The Revised Model*

The restructured NCRM has a significantly more complex topology than the SWMC model from which it is derived. The layout presented as Figures 4.3 and 4.4 has resulted from a number of preliminary layouts of increased complexity.

A compromise was sought between accuracy required and model detail. Increases in detail resulted in increased computation times. In addition, the limited information available for flood plain inundation calibration did not justify a large number of link structure. The present level of detail is regarded as being a workable compromise which should yield satisfactory results for use at planning and pre-feasibility level on a regional scale.

Figure 4.3 Schematised North Central Region Model (North)

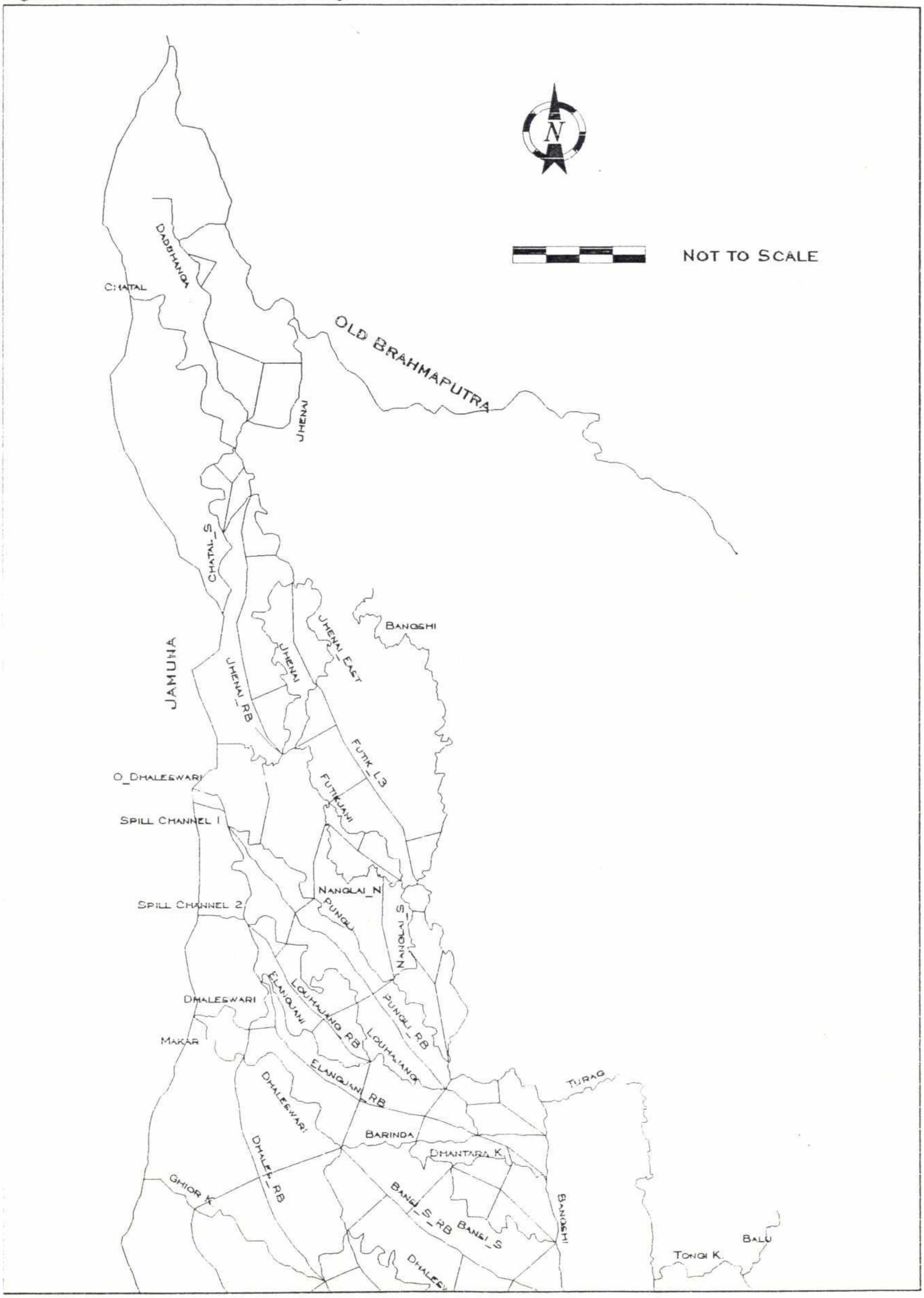


Figure 4.4 Schematised North Central Region Model (North)

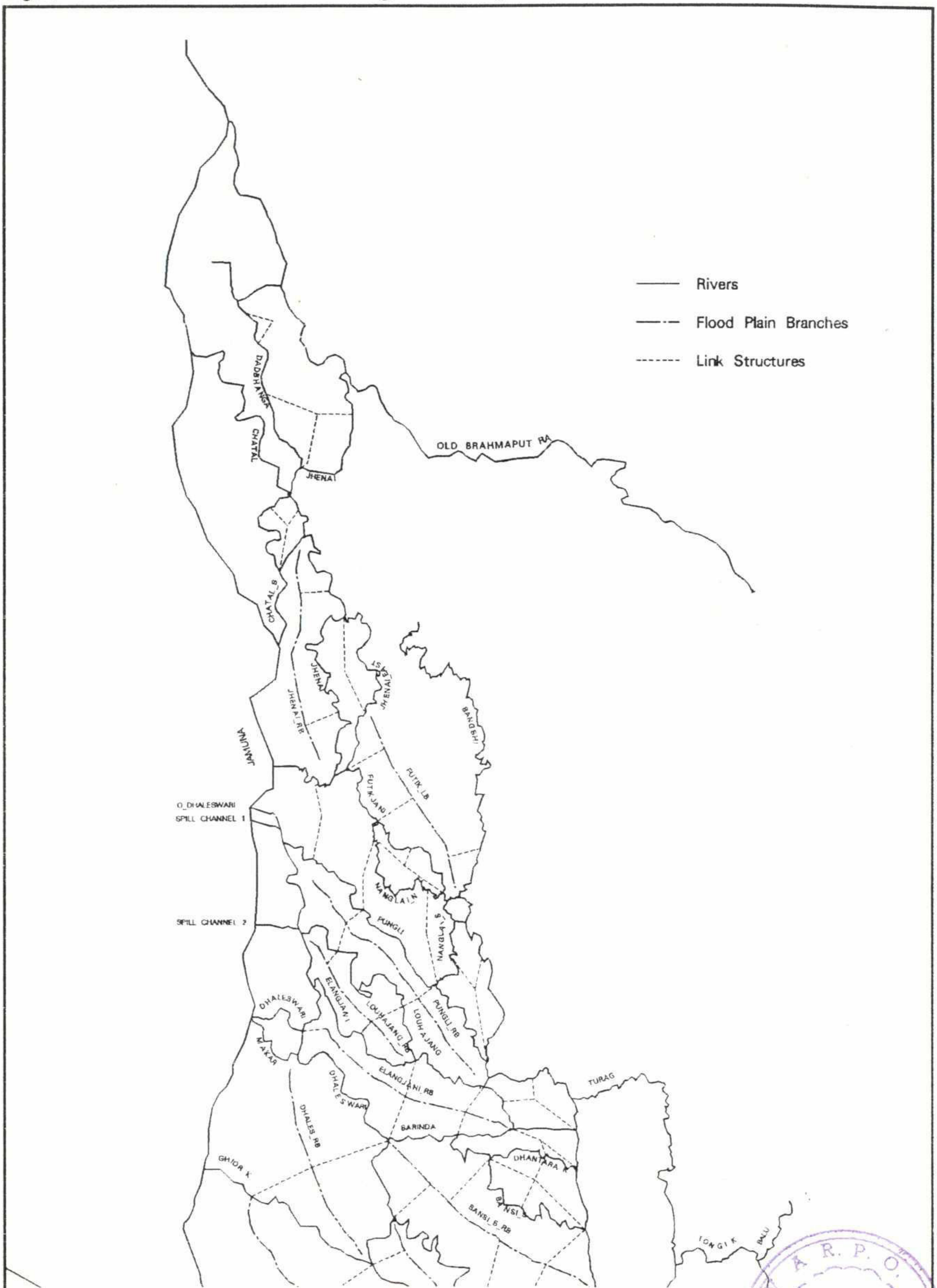


Figure 4.5 Schematised North Central Region Model (South)

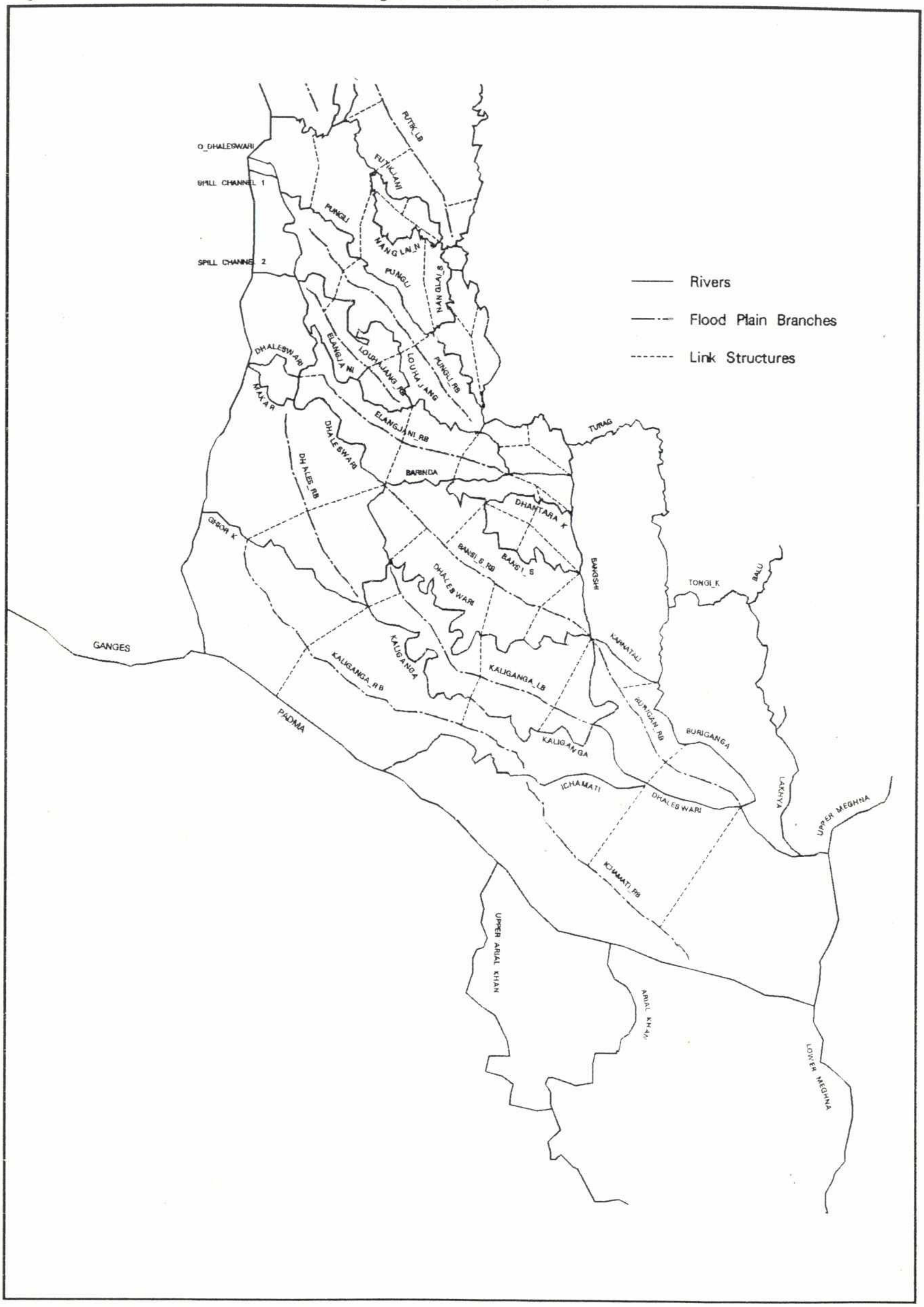
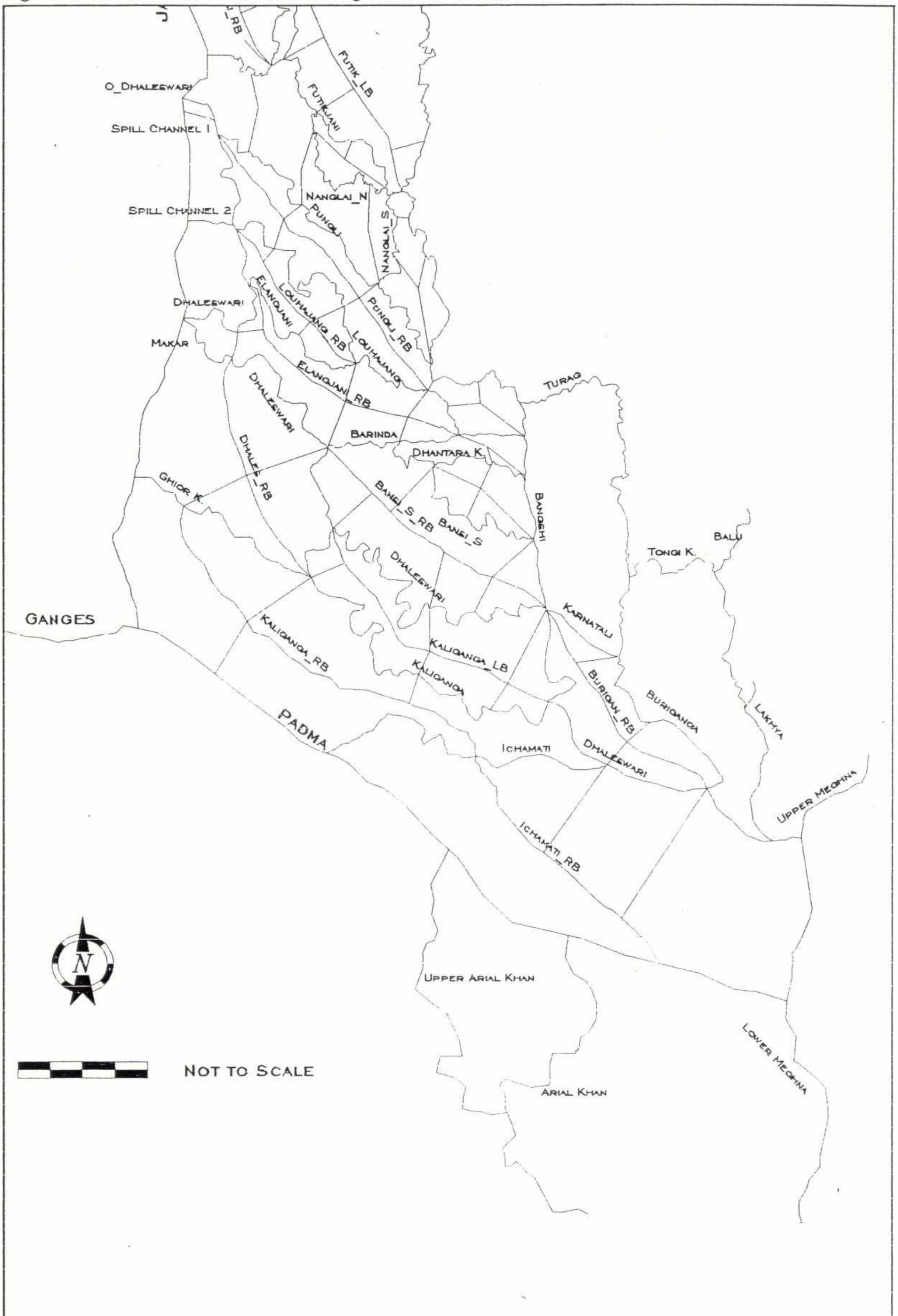


Figure 4.4 Schematised North Central Region Model (South)



4.3 Model Calibration

It was originally intended to calibrate the NCR FMM for 1993, having regard for the additional hydrometric information available throughout the region for that year. Unfortunately, essential data from BWDB was not available when calibration was to commence, and therefore work was initially started on 1991, for which all data was available. Verification, however, will be based on the data for 1993.

The revised structure of the model increased the complexity of the calibration significantly. In addition to the requirement for agreement between modelled and recorded water levels and discharges in the rivers, a sensible representation of the flooding characteristics on the flood plain was also needed. At this time, however, in the absence of any suitable imagery, only a subjective assessment of this calibration can be made. It is anticipated that radar imagery for part of the region will be made available shortly, and this will be used to verify original assumptions for flood plain inundation in the best way possible. However, as stated in previous reports, some caution must be exercised in the interpretation of the radar imagery.

While the major calibration exercise has been completed, it is anticipated that further "fine tuning" will take place throughout the remaining duration of the project, as further corroborative evidence becomes available.

Sample calibration results are presented in this report as Figures 4.5 and 4.6. Examples have been given for stations in areas which were not well simulated in the SWMC model. It may be seen that the revised structure gives a considerably better agreement in these areas, indicating that quasi 2-dimensional structuring was justified. Additional work is needed for better agreement during the flood recession period and it is anticipated that inclusion of khals, (for discharge of water from the floodplain), will improve this.

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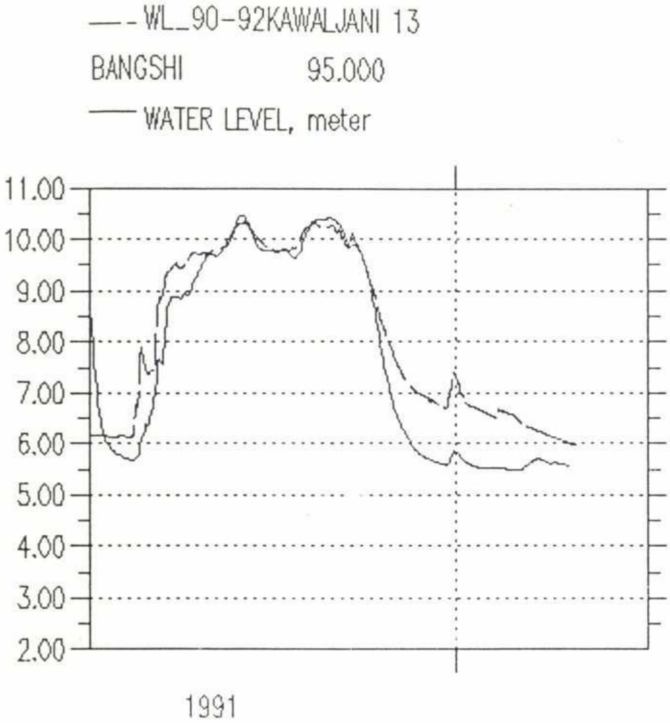
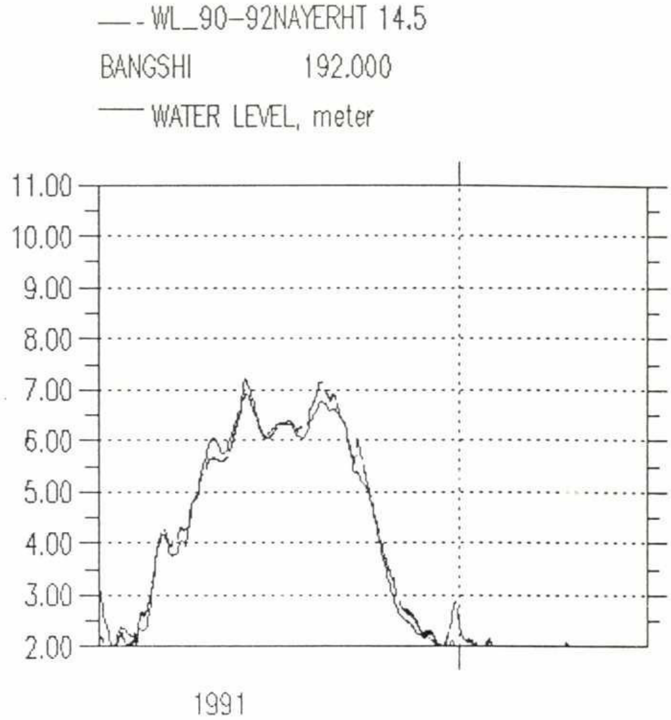
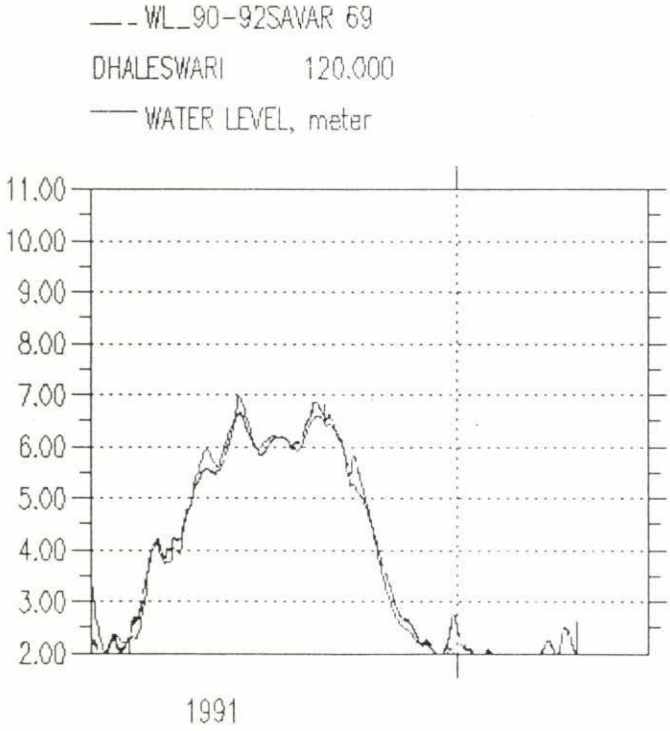
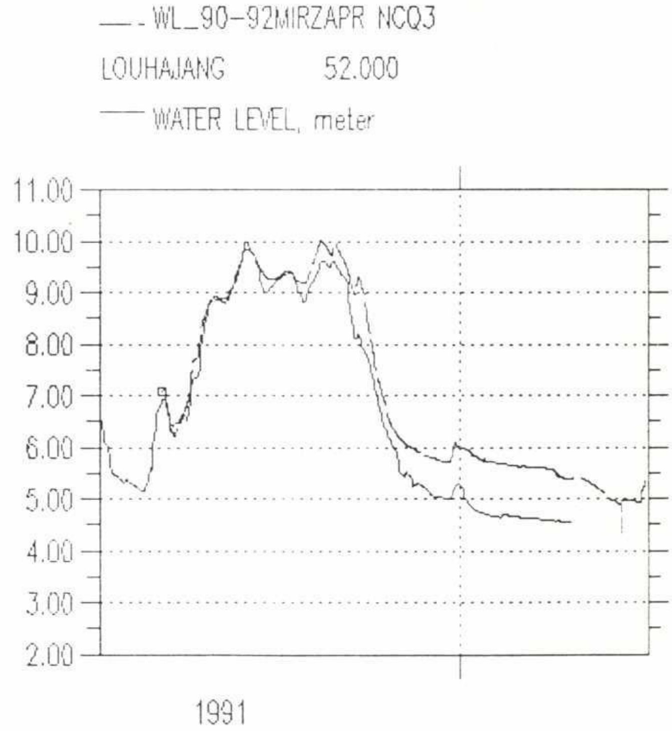






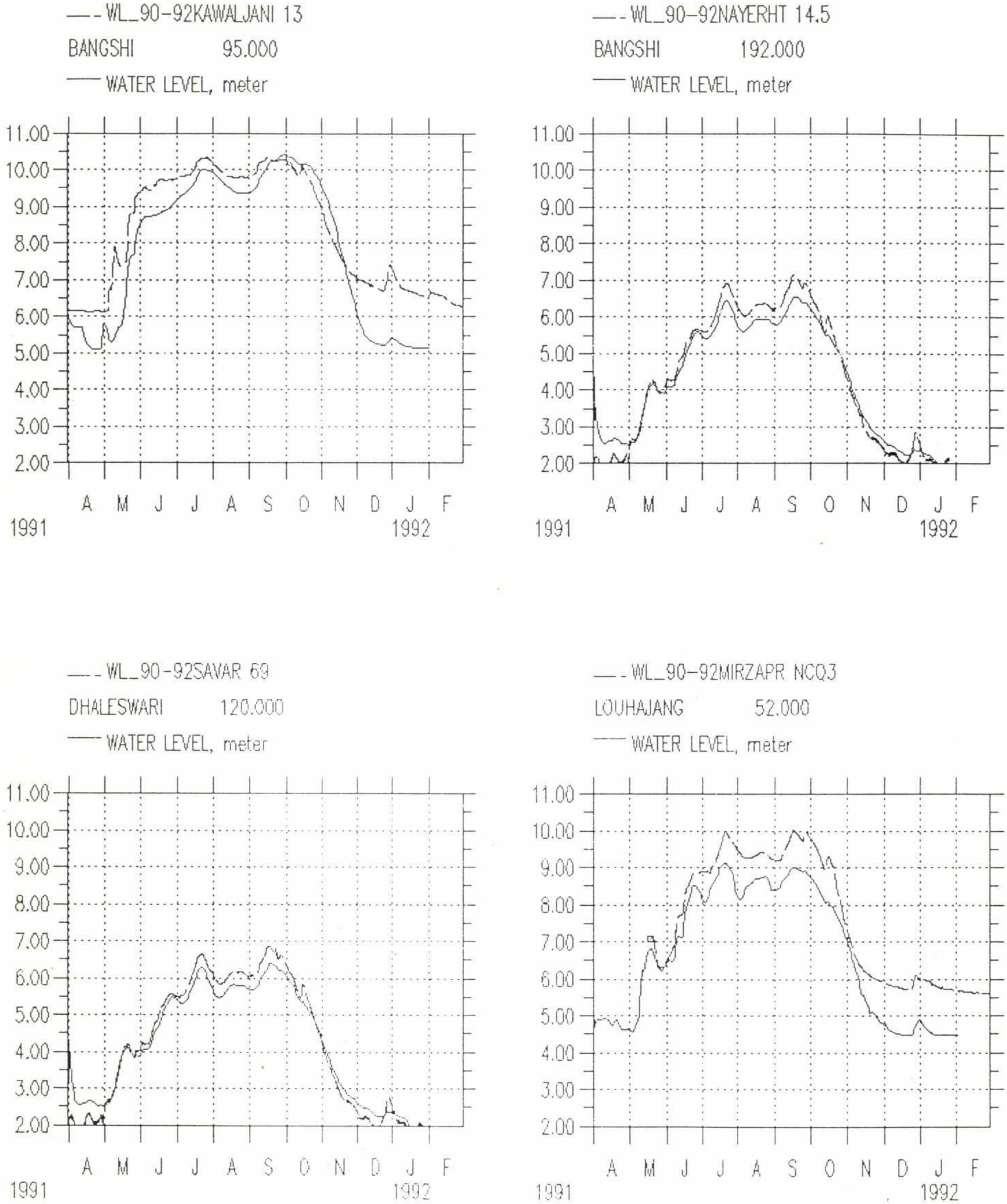


DATA FILE : C300_021.RDF
RESULT FILE : C300_035.RRF

BOUNDARY FILE : C300_003.BSF
CALCULATED : 21-APR-1994, 13:55

MIKE 11

Figure 4.5



DATA FILE : NC-SWMC.RDF
RESULT FILE : NCC-SWMC.RRF

BOUNDARY FILE : NC-SWMC.BSF
CALCULATED : 6-MAR-1994, 14:39

MIKE 11

Figure 4.6

4.4 Flood Mapping

4.4.1 Use of MIKE11-GIS

Having used MIKE11-GIS in its role as a topographic data exporter, (for the restructuring of the NCR FMM), the production of flood maps uses the software tool to integrate the MIKE11 results with the GIS-based information. In this Interim Report, only a brief outline of procedures used will be given, since the Final Report will contain full details of any refinements developed over the application stage.

Using the existing rivers coverage in the GIS, a Branch Route System for the NCR base, (unmodified), case was digitised. This activity relates the MIKE11 network to the "real world" and identifies river branches, h-points and flow directions. The alignment of the rivers in the BRS generally follows that in the rivers coverage, although the latter does not contain any flood plain branches, since these are largely conceptual.

In order for the water surface to be defined, the extent to which each calculated water level in the model applies was then digitised on the Water Surface Coverage. Channel boundary lines, which define the lateral extent of the river water levels, were input. These generally followed the alignment of the rivers, but the DEM was used as a guide to identify low spots adjacent to the river where the water level would be governed by the river level. In the same way, channel boundary lines for the flood plain branches were digitised. Flood cells were delineated in the same way, the water level within each cell being horizontal and equal to the water level at the nodal point within the cell.

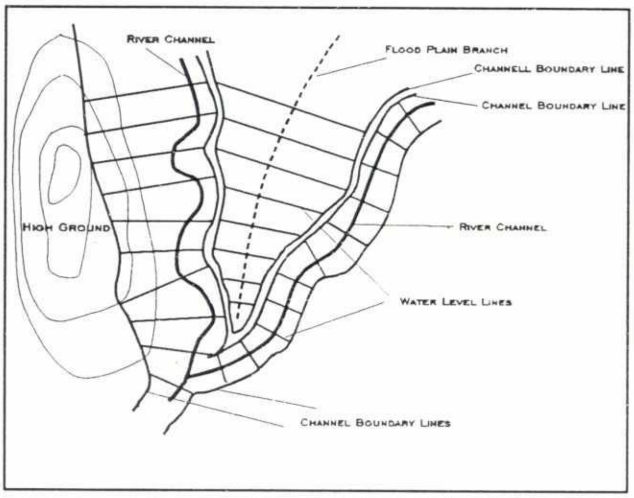


Figure 4.7 Channel Boundary Lines & Water Level Lines

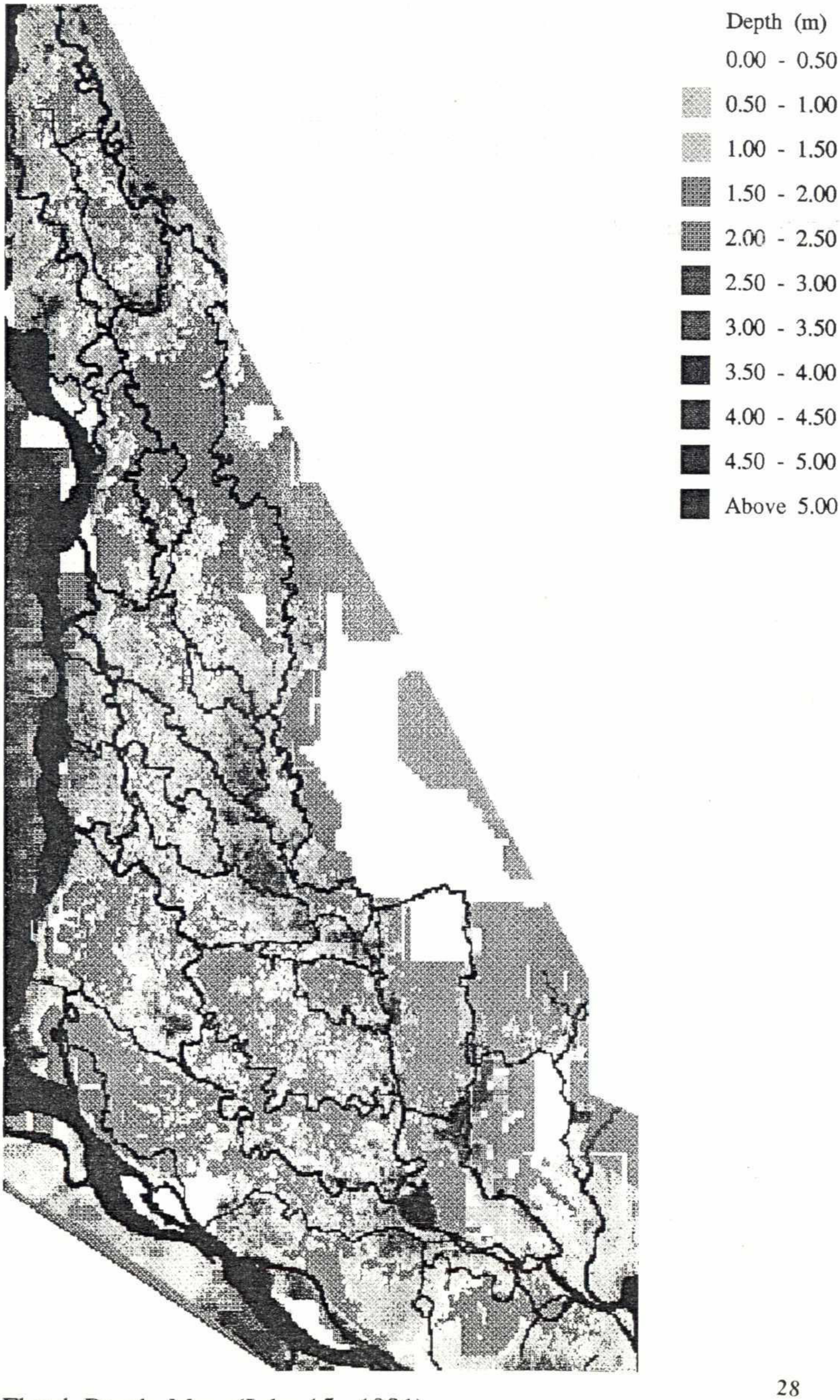
Within each channel boundary line, water level lines were defined, approximately at right angles to the direction of flow. Water levels are horizontal along these lines, their values being interpolated between adjacent h-points along the river branch. Figure 4.7 gives an illustration of the use of channel boundary lines and water level lines.

The penultimate stage in MIKE11-GIS activities is largely automatic. The software generates a Triangulated Irregular Network, (TIN), which is a template for the interpolation of water levels throughout the model. It ensures that water level across each water level line is horizontal, but that the overall water surface slopes in a downstream direction depending on adjacent h-point values from the hydrodynamic calculation.

From the output of water levels from the MIKE11 simulation, flood maps were produced by overlaying the water surface with the DEM.

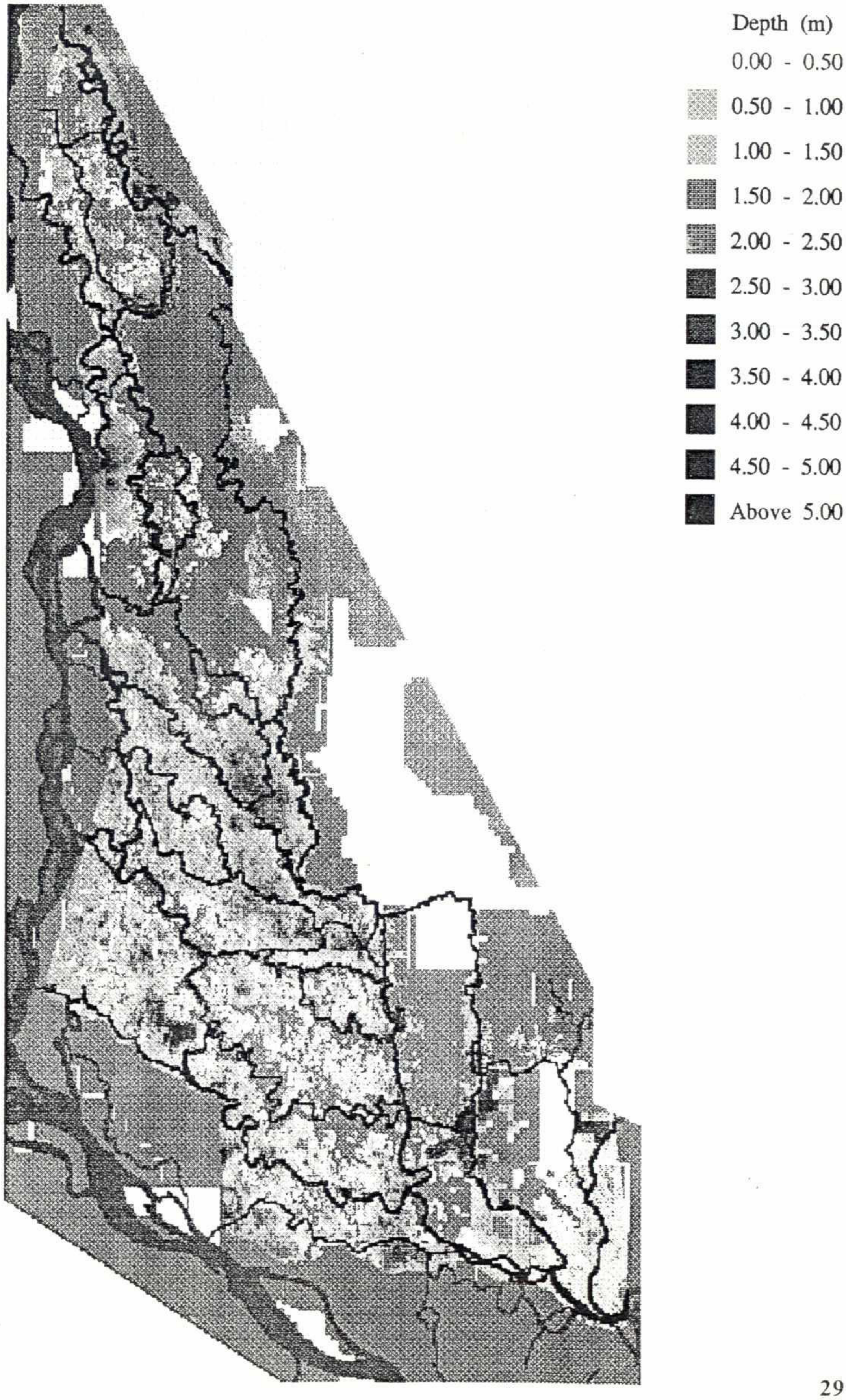
Figure 4.8

Flood Depth Map
North Central Region - Revised NCRM Setup



Flood Depth Map (July 15, 1991)

Flood Depth Map
North Central Region - SWMC Model Setup



Flood Depth Map (July 15, 1991)

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4.4.2 Flood Maps

In order to illustrate the difference between flooding indicated by the NCR FMM and that by the SWMC model, two flood maps were produced. These are given as Figures 4.8 and 4.9. It can be seen that the flood characteristics of the flood plain are represented in a much more realistic way by the NCR FMM. This is primarily due to the separation of the flood plains from the rivers, permitting level differences between the two entities. Flood water is seen to accumulate at the downstream end of the flood plains, which is clearly the case in reality.

The flood map based on the SWMC basic model is unable to show flooding in areas adjacent to the boundary rivers, since these rivers are not included in the model. This clearly illustrates the need for their inclusion in the FMM model. In addition, much of the flooded area shown on the SWMC-based map is derived from interpolation of water levels between two adjacent, but distant, rivers. The derivation of flood plain inundation on this basis is not justified unless a clear interconnection is present, which is not always the case.

4.5 Demonstration Runs

Demonstration of the use of MIKE11-GIS on a regional scale is called for in the Terms of Reference and is stated as follows:-

- build a regional FMM for the North Central region and carry out FMM demonstration runs showing the effects of different structural arrangements and operations under different flooding conditions and produce flood hazard maps for various historic floods and return periods;
- initiate, on this basis, the establishment of a database of simulated historic events, (e.g. 1987 and 1988), which can assist, (in the long term), to identify optimal operation strategies in real-time situations, but in the short term and within the present study may serve the purpose of demonstration of the possible benefits of FMM without having to run the hydrodynamic part;
- demonstrate the effects of flood retention in a series of successive compartments on the flood conditions around Dhaka;
- make the DEM for the NCRM, including interfacing to MIKE11 output and graphic modules available for FAP 10 and test, in cooperation with FAP 10, the possibilities of deriving, off-line, relationships between river water levels and flood plain inundations, also considering the effect of direct rainfall, to be used in conjunction with real-time river level forecasting on a regional level.

The demonstration runs will be based on the concept of the construction of hypothetical compartments in the Mirzapur area. This area may be defined as the area bordered by the Kaliganga in the south, the Bangshi in the east, the Barinda in the north and part of the Dhaleswari and Kaliganga in the west. Employing this concept permits the requirements of the Terms of Reference to be addressed implicitly, since the components of compartmentalisation, (embankments, gates and different arrangements thereof), cover most of the available options. In addition, the relative effect of compartmentalisation on the flood levels around Dhaka may be demonstrated.

The structural elements included in the application exercise will consist of embankments along the main watercourses, together with smaller embankments dividing adjacent sub-compartments, (where appropriate).

Offtake discharges from the Dhaleswari into the Barinda and the discharge retained in the Dhaleswari at its bifurcation with the Kaliganga may be restricted by the imposition of major control structures at the offtakes. Restriction of discharge along these watercourses could assist in the drainage potential from the flood plain compartments, (also contingent on the backwater effects from the boundary rivers).

The hypothetical scenario will be developed in a phased manner, by firstly constructing structures and embankments in a suitable combination and extent, followed by the compartment construction, also in phases. In this way, the use of MIKE11-GIS , with the hydrodynamic model incorporating various elements of the total structural options, will be demonstrated.

The concept of water management, on a regional scale, will be demonstrated by setting up additional hypothetical compartments in another part of the region, (probably the Bangshi - Futikjani area), where the conjunctive operation of both this and the Murzapur compartments may be illustrated. This would depend on the possibility of retaining water in one compartment such as to permit the draining of another.

In each of the above cases, MIKE11-GIS will be used to produce typical maps of flood depth and accompanying tables. These examples will show the type of output that would be available for users, given that a suitably calibrated and representative hydrodynamic model were available for their area of interest.

While the above activities provide suitable "scenarios" for the demonstration of the use of MIKE11-GIS, they are largely activities related to the hydraulic modelling using MIKE11. Emphasis will not be placed solely on the hydraulic modelling aspects of MIKE11-GIS. Of more use to future users of the tool will be a demonstration of the effects on the output of adopting different alternatives within the post-modelling processes, for example, different DEM grid spacings, larger or smaller water surface grids, different spacing of water level lines in the water surface coverage, and different TIN densifications.

All these factors contribute to the efficiency of use of the tools and by demonstrating the "sensitivity" of such factors, (on a regional scale), future users will be better equipped to appreciate both the data needs and the presentation options available for regional scale work with MIKE11-GIS.

The use of MIKE11-GIS for flood forecasting activities on a regional scale is contingent on FAP-10. It is unlikely that this study will be in-place before the conclusion of FAP-25 and, therefore, activities related to flood forecasting cannot be programmed at this time.

09

5 THE TANGAIL COMPARTMENT FMM

5.1 Introduction.

The previous Interim report No. 1, presented the progress on the Tangail Compartment Model (TCM) update and the development of the Tangail FMM including the initial test application. This Chapter of the Interim Report presents the refinements made to the TCM and works carried out on the Tangail FMM. The TCM model (basic model), developed by FAP-20 - Compartmentalization Pilot project (CPP), has been refined based on an updated DEM and using the MIKE11-GIS software. The refined model is being calibrated again for 1993.

In order to test the structure operation, the north-eastern part of the Tangail Compartment Model has been selected, the schematization of which represents the hydraulic features in more detail.

5.2 Model Refinement.

5.2.1 The Basic Model.

For FAP 20, a mathematical model of the Tangail compartment, based on the MIKE11 software, has been developed which has been used as a tool in the planning stage of the project. This model consists of two modules, the hydrological model NAM and the hydrodynamic model.

The Tangail compartment is divided into 16 sub-compartments including Tangail town. These sub-compartments are again divided in smaller parts finally resulting in a total of 24 rainfall-runoff catchments which assure a proper rainfall-runoff distribution in the compartment. For all catchments runoff to the various locations of the open channel network has been computed using the hydrological module NAM for the selected periods. Apart from the sub-compartments, the Lohajang floodplain is also included in the model studies.

The hydrodynamic model comprises 25 channels connected at 13 nodes. The upstream boundary of the model is extended to the Dhaleswari offtake. The downstream boundaries are taken in the Lohajang river at Mirzapur, in the Pungli river at the southern border of the project and in the Dhaleswari river at the junction with the New Dhaleswari river.

All the schematized channels were surveyed from November 1991 onwards and the collected channel cross-section profiles are used in the model. The relevant cross-section profiles of the Old Dhaleswari, Elanjani and Pungli rivers have been collected from FAP-3. The flood plain data were collected from the BWDB maps of 8 inch to a mile scale with 1 ft. contour interval from 1964. The maps were used to prepare area-elevation curves for every sub-compartment.

The basic model has been calibrated against the 1991 situation for the period May to November (14 water level measuring stations were installed in the Tangail Compartment in May 1991). The overall calibration showed a good agreement between measured and computed data. Comparison of the model simulation data with the observed data of 1992, however, showed a poor match. It was suspected that this mismatch could be due to inappropriate representation of the flood plain in the basic model.

of

5.2.2 *Floodplain Representation.*

In the basic model, the flood plain was mainly attached to the river in the cross-section, which had little effect on the calibration of 1991 because of a constant high water level throughout the period. This approach, however, did not show good results for 1992 which was a relatively "dry" year.

In order to study the impact of internal structural and non-structural (operation / management) interventions under a comprehensive water management plan of the (sub-) compartments, it was found necessary to refine the model to represent the flood plain flooding more accurately.

At flood plain level, the khals are connected with the flood plain at various locations. Therefore the flood plain has been schematized as additional storage for most of the area. The additional storage areas have been extracted from the new DEM developed by digitizing the FINNMAP topo-photo maps.

5.2.3 *Use of MIKE11-GIS.*

Using the Topographic Data Module of MIKE11-GIS, merging of floodplain cross-section profiles, (extracted from the DEM), with surveyed cross-sections in the MIKE11 model has been tested. It was difficult to achieve an acceptable merged cross-section, which may be due to the inaccuracy of the location of the cross-sections in the surveyed channels, especially in the low lying areas.

The same module has been used to extract the additional storage areas from the DEM and to export the areas to specified cross-section profiles in the MIKE11 input.

5.2.4 *The Refined Model.*

NAM-model.

The NAM sub-catchments have been re-defined due to inclusion of new channels and khals. The collected rainfall and groundwater data have been used for the calibration of the NAM-model of the Tangail Compartment. The NAM parameters have been selected based on previous modelling experience in this area.

Hydrodynamic model.

The following improvements have been made to the basic TCM model ,(see Figure 5.1 and Table 5.1):

- all cross-sections have been checked with the latest surveys and adjusted where necessary (including the 1992 excavation)
- the improved inlet at Fatehpur khal

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Figure 5.1

Tangail Compartment Model

Table 5.1 Cross-reference list of TCM-channels 1993 model.

Channel	at km	connected with	at km	connected with	at km	Boundary	Gauge
AOLOA	0.00	LOHAJANG	15.00				
AOLOA	2.50	INDRABELTA	2.00				
AOLOA	1.25	KAGMARI	1.60				
AOLOA	3.74	BINNAFAIR	5.30	GAIZABARI	0.00		G22
ATIA-DEOJAN	0.00	LOHAJANG	17.75				G05
ATIA-DEOJAN	1.75	KAGMARI	4.00				
ATIA-DEOJAN	4.55	BARUHA	3.31				
ATIA-DEOJAN	5.31					G25	
BALLY	0.00	LOHAJANG	10.50				G02
BALLY	1.27	BANIABARI	4.20				
BALLY	1.946	SADULLAPUR	2.60				G30
BANIABARI	0.00					Q=0	
BANIABARI	2.25	MAGUR	0.00				(G34)
BANIABARI	4.25	SADULLAPUR	2.60				
BARUHA	0.00	ELA	6.00				(G37)
BARUHA	3.31	ATIA-DEOJAN	4.55				
BATHKURA	0.00	SADULLAPUR	6.85	GARINDA	0.00		G31
BATHKURA	1.60	SURAJ	0.90				
BATHKURA	3.15	NAMDAR	5.00				(G32)
BATHKURA	5.71	LOHAJANG	26.00				
BBASALIA	0.00					Q=0	
BBASALIA	4.64	PUNGLI	12.00				
BELTASARAI	0.00	ELA	2.75				G10
BELTASARAI	2.50	KAGMARI	3.00				
BINNAFAIR	0.00	ODHA	26.00				G21
BINNAFAIR	3.00	SINGARKONA	6.50				
BINNAFAIR	4.70	FATEHPUR	3.50				
BINNAFAIR	5.30	GAIZABARI	0.00	AOLOA	3.70		G22
CHILLABARI	0.00	LOHAJANG	7.90				
CHILLABARI	3.40	GAIZABARI	0.80				
ELA	0.00	ODHA	29.50				
ELA	2.00	INDRABELTA	0.00				
ELA	2.75	BELTASARAI	0.00				G10
ELA	6.00	BARUHA	0.00				
ELA	25.00	LOHAJANG	37.50				
FATEHPUR	0.00	ODHA	27.00				
FATEHPUR	3.50	BINNAFAIR	4.70				
GAIZABARI	0.00	BINNAFAIR	5.30	AOLOA	3.70		G22
GAIZABARI	0.80	CHILLABARI	3.40				
GAIZABARI	2.35	LOHAJANG	13.00				G03
GALA	0.00	LOHAJANG	4.00				G01
GALA	4.00	SADULLAPUR	0.00				G29
GALA	5.00	RASULPUR	0.00				G28
GALA	7.775	PUNGLI	15.50				G13
GARINDA	0.00	BATHKURA	0.00	SADULLAPUR	6.80		G31
GARINDA	4.15	JALFAI	0.00				
INDRABELTA	0.00	ELA	2.00				(G33)
INDRABELTA	2.00	AOLOA	2.50				
JALFAI	0.00	GARINDA	4.15				
JALFAI	1.016	LOHAJANG	25.00				G06
JUGINI	0.00	LOHAJANG	3.00				(G23)
JUGINI	3.00	LOHAJANG	6.53				G36

(Gxx): gauge nearby in khal or floodplain.

Table 5.1 Cross-reference list of TCM-channels 1993 model (continued).

Channel	at km	connected with	at km	connected with	at km	Boundary	Gauge
KAGMARI	0.00					Q=0	
KAGMARI	1.60	AOLOA	1.25				
KAGMARI	3.00	DHA4	2.50				
KAGMARI	4.00	ATIA-DEOJAN	1.75				
KUMULI	0.00	LOHAJANG	27.00				
KUMULI	2.90					G26	
LOHAJANG	0.00	ODHA	23.00				G35
LOHAJANG	2.00	MALANCHA	3.00				
LOHAJANG	3.00	JUGINI	0.00				
LOHAJANG	4.00	GALA	0.00				G01
LOHAJANG	6.53	JUGINI	3.00				(G36)
LOHAJANG	7.90	CHILLABARI	0.00				
LOHAJANG	10.50	BALLY	0.00				G02
LOHAJANG	13.00	GAIZABARI	2.35				G03
LOHAJANG	15.00	AOLOA	0.00				
LOHAJANG	17.75	ATIA-DEOJAN	0.00				G05
LOHAJANG	25.00	JALFAI	1.010				G06
LOHAJANG	26.00	BATHKURA	5.71				
LOHAJANG	27.15	KUMULI	0.00				G08
LOHAJANG	37.50	ELA	25.00				
LOHAJANG	53.00					Mirzapur	
MALANCHA	0.00	ODHA	18.50				
MALANCHA	0.00	LOHAJANG	2.00				
MAGUR	0.00	BANIABARI	2.25				(G34)
MAGUR	2.00	SADULLAPUR	1.50				
NAMDAR	0.00					Q=0	
NAMDAR	5.00	BATHKURA	3.15				(G32)
ODHA	0.00					Sirajganj	
ODHA	6.54	SPCHANNEL1	6.543				
ODHA	10.00	PUG	0.00				
ODHA	18.50	MALANCHA	0.00				
ODHA	21.70	SPCHANNEL2	7.20				
ODHA	23.00	LOHAJANG	0.00				G35
ODHA	26.00	BINNAFAIR	0.00				G21
ODHA	27.00	FATEHPUR	0.00				G10
ODHA	29.50	ELA	0.00				
ODHA	38.00					G16	
PUG	0.00	ODHA	10.00				
PUG	12.00	BBASALIA	4.64				
PUG	15.50	GALA	7.775				G13
PUG	18.00	SURAJ	3.875				
PUG	31.50					G14	
RASULPUR	0.00	GALA	5.00				G28
RASULPUR	3.809	SADULLAPUR	3.70				
SADULLAPUR	0.00	GALA	4.00				G29
SADULLAPUR	1.50	MAGUR	2.00				
SADULLAPUR	2.60	BALLY	1.946				G30
SADULLAPUR	3.70	RASULPUR	3.809				
SADULLAPUR	6.85	GARINDA	0.00	BATHKURA	0.00		G31
SINGARKONA	3.00					Q=0	(G24)
SINGARKONA	6.50	BINNAFAIR	3.00				
SURAJ	0.90	BATHKURA	1.60				
SURAJ	3.875	PUNGLI	18.00				
SPCHANNEL1	0.00					Sirajganj	
SPCHANNEL1	6.543	ODHA	7.073				
SPCHANNEL2	0.00					Sirajganj	
SPCHANNEL2	7.20	ODHA	21.726				

(Gxx): gauge nearby in khal or floodplain.

- the Chillabari khal (excavated), Kagmari khal, connecting Aoloa and Atia-Deojan khal, and Surooj khal, connecting Bathkura khal and the Pungli river (closed) have been included in the model
- the flood-plain has been removed from the cross-section profiles of the khals
- the additional storage areas, extracted from the DEM, have been combined with the surveyed MIKE11 cross-section profiles

The revised hydrodynamic model comprises 32 channels connected at 37 nodes.

The location and type of the boundaries in the refined model are shown below.

River/khal name	Location	Station	Type
Old Dhaleswari	Upstream	Sirajganj	Water level
Old Dhaleswari	Downstream	G16	Water level
Lohajang	Downstream	Mirzapur	Water level
Pungli	Downstream	G14	Water level
Baniabari	Upstream		Q=0.0
Bbasalia	Upstream		Q=0.0
Namdar	Upstream		Q=0.0
Kagmari	Upstream		Q=0.0
Singarkona	Upstream		Q=0.0
Atia-Deojan	Downstream	G25	Water level
Kumuli	Downstream	G26	Water level

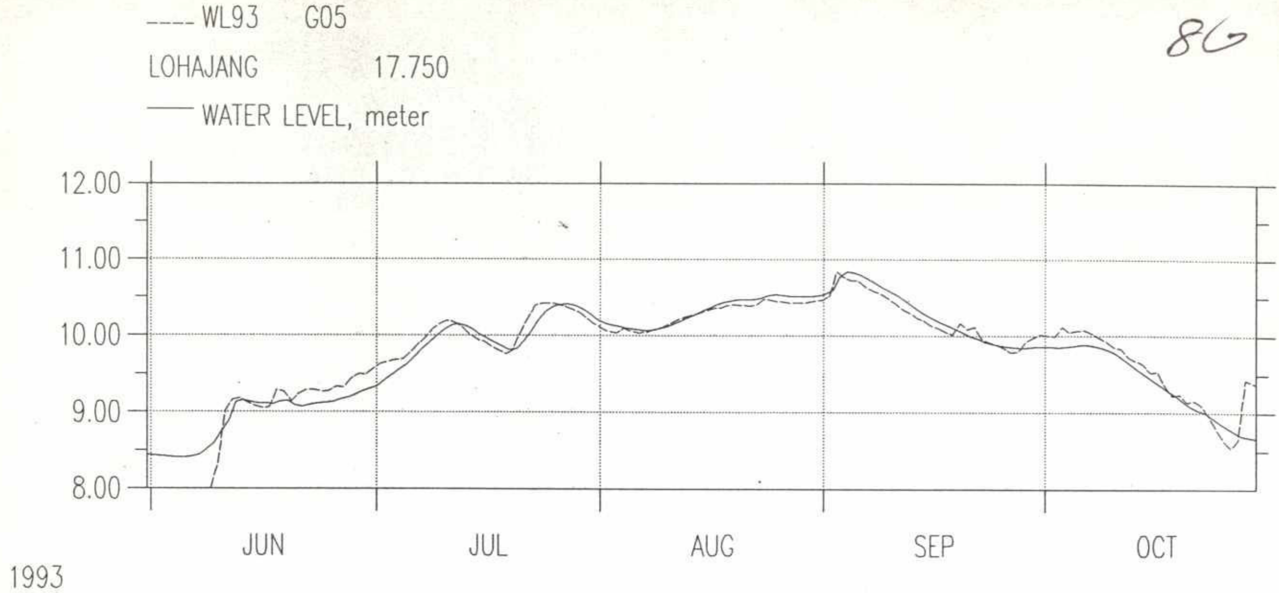
For the calibration of the refined model for 1993, only one structure had to be included. Although 3 structures existed in the Tangail Compartment, only Binnafair inlet was in operation. Jugini and Fatehpur inlets were closed during the 1993 wet season.

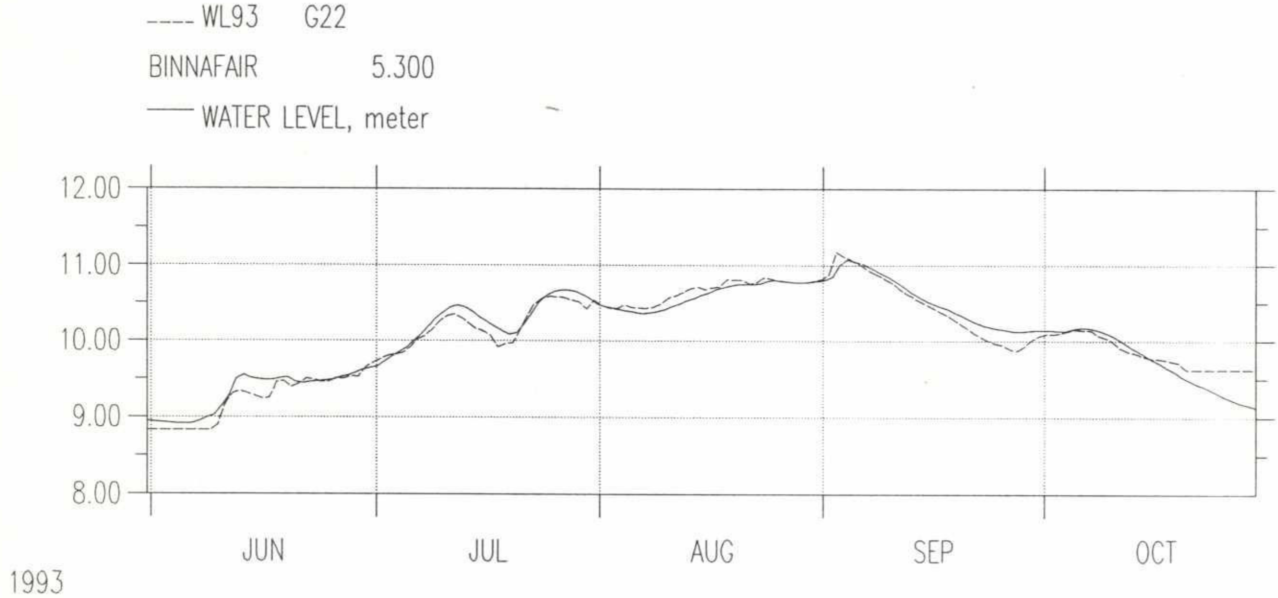
5.3 Model calibration.

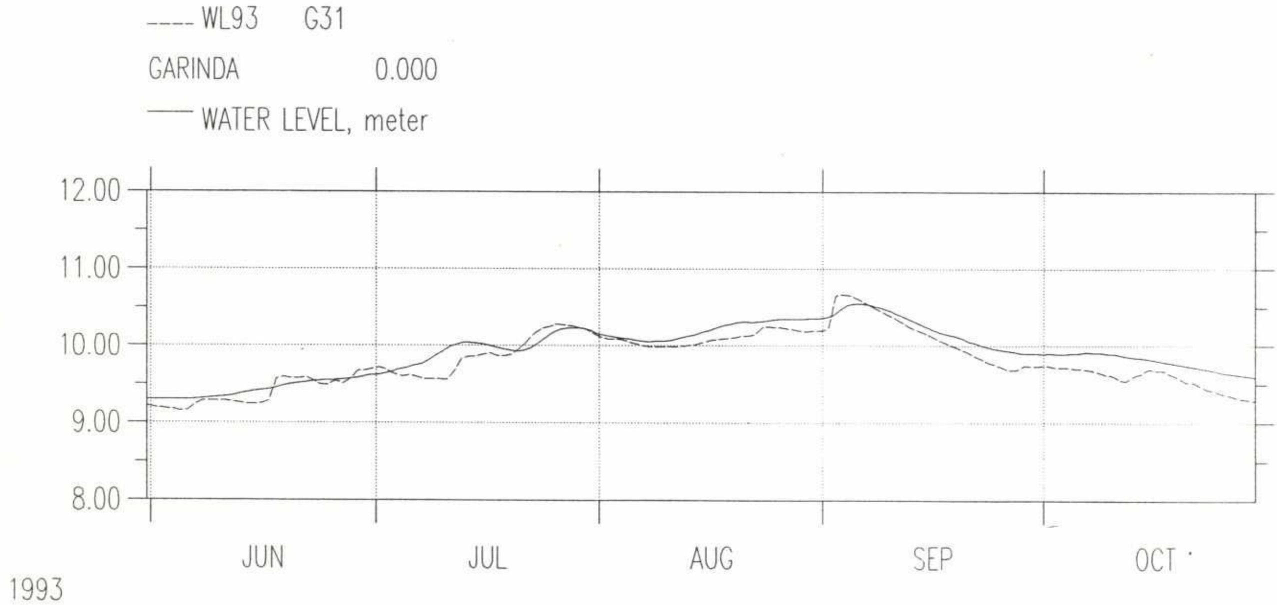
Results.

The initial calibration results for 1993 already showed a good agreement between computed and observed water level data, (see the Lohajang and Binnafair locations in Figure 5.2), especially in the western part of the Compartment. The eastern part still needs some improvements, (see Garinda location in Figure 5.2).

There still exists a problem in the datum uncertainty originating from the locally varying, unknown difference between PWD and the FINNMAP-datums. The FINNMAP datum is converted to PWD datum by using a general factor. The PWD datum is used in the surveyed cross-section profiles







Tangail Compartment Model

Calibration for 1993

MIKE 11

DATA FILE : BASE-TCM.RDF
RESULT FILE : BASE-AE1.RRF

BOUNDARY FILE : BASE-TCM.BSF
CALCULATED : 24-MAR-1994, 10:16

Dwg no.: Figure 5.2

while the FINNMAP datum is used in the DEM and hence the additional storage levels. Each of the additional storage data extracted from the DEM has to be checked by comparing it with the respective cross-section profile.

Only the 4 discharge measurements in August 1993 at a few locations in the Lohajang could be compared with the computed ones (Figure 5.3). A good agreement is seen between the simulated and observed discharges near G36 but the computed discharge is too high at the downstream reaches of the Lohajang. More discharge measurements are needed to arrive at a reasonable conclusion.

Due to change in priority of the work tasks, the calibration has not been finalised. It is planned to continue with the calibration work after carrying out some preliminary tests on structure operation with the model including a detailed schematization of sub-compartments 9, 10 and 11.

5.4 Flood mapping.

5.4.1 Preparation.

FINNMAP photo maps have been digitized to obtain an updated DEM. All the available coverages (rivers, khals and roads) have been transferred from FAP-19. Further details have been made available from the CPP which have been included in the revised coverages. The coverage of the river/khal system has been adjusted to the detailed model schematization.

Before the production of flood maps, it was necessary to export certain information from MIKE11 to MIKE11-GIS in order to ensure that the results of MIKE11 were correctly reflected in the flood maps. The automatic procedure developed by FAP25 is used to convert the MIKE11 results and model information into binary formats efficiently imported into the Arc/Info files to be used during the water surface generation by MIKE11-GIS.

5.4.2 Use of MIKE11-GIS.

In order to produce flood maps, a Branch Route System (BRS) for the relevant model scheme was made and calibrated. Channel boundary lines were digitized along with the water level lines. The process of developing flood maps is briefly described in Chapter 4 (see Section 4.4).

5.4.3 Initial outputs

Flood depth maps and flood depth difference maps for the 1993 simulation have been produced as examples. Figure 5.4 shows a flood depth map for September 4, 1993 simulated as a base situation. Comparison with the preliminary RADAR image for the same area shows quite good agreement. However, the RADAR imagery is being refined by FAP19 and it is hoped that such imagery will be useful for model verification in the future.

To further illustrate the FMM application, Figure 5.5 shows another flood depth map for a situation simulated with the proposed additional peripheral structures in the Tangail compartment.

A difference map is produced as shown in Figure 5.6 by taking a difference between the flood depths of the existing and with-structures conditions. This figure indicates the positive and negative impacts of the proposed peripheral structures by showing areas where the flooding will decrease or increase.

80

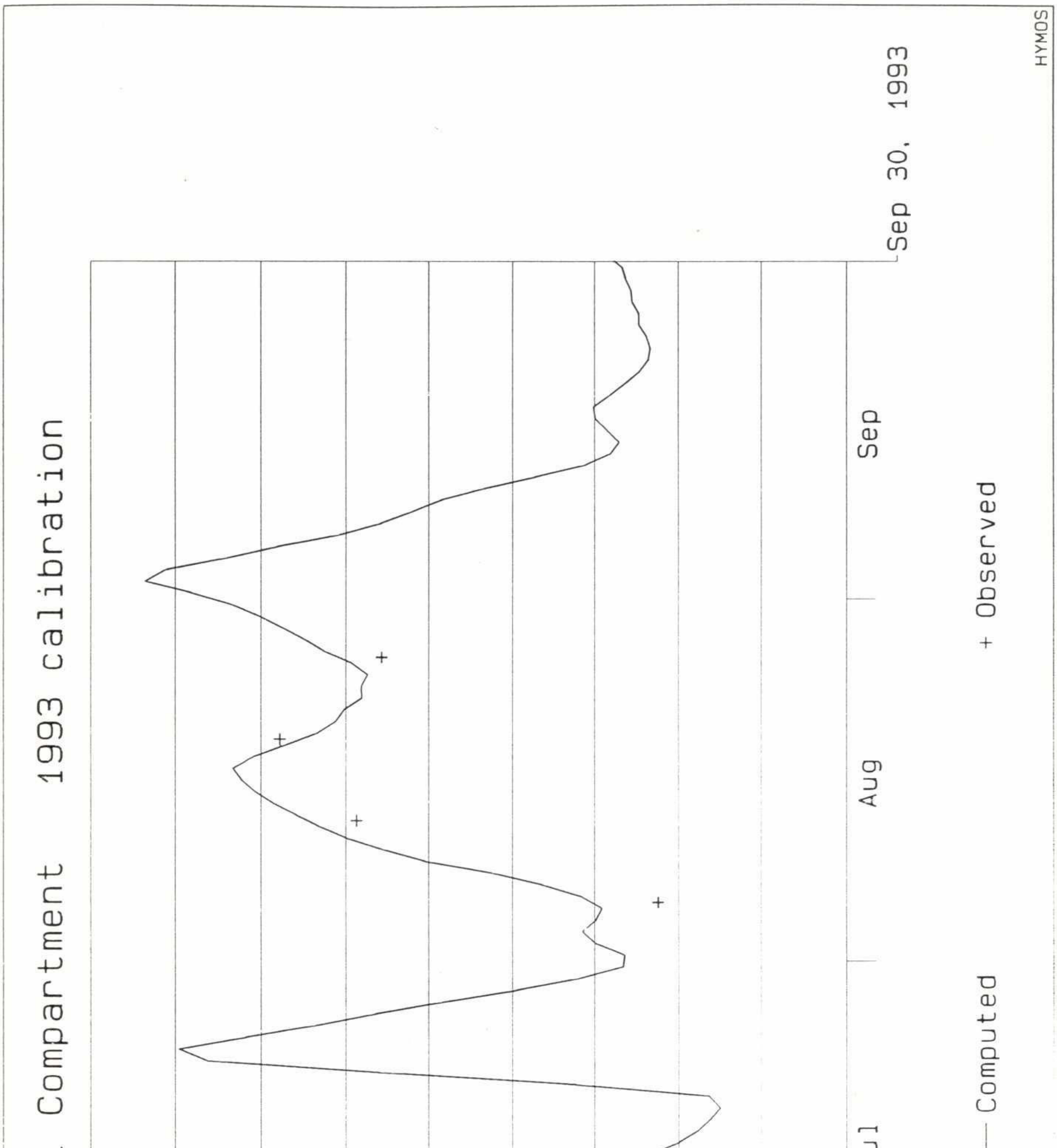


Figure 5.3 Discharge Lohajang at Dithpur (G36)

8y

The difference map will form the basis of further impact analysis in combination with other GIS overlays such as land use, crops and fisheries data.

5.5 Structure operation modelling.

A start has been made with a detailed schematization of the cluster of sub-compartments 9, 10 and 11 (up to chawk level), especially for testing structure operation and to develop structure operation guidelines.

The general operational requirement comes from agriculture and fisheries and the water level requirement has been calculated for each chawk. For modelling purposes also the average field level of the chawks has been supplied (see Figure 5.7 and Table 5.2).

The proposed khals and structures as well as some floodplain channels have been included in the detailed part of the model (see Figure 5.7 and Table 5.3). The chawks have been combined with the cross-section profiles as additional storage, obtained from the average field level and chawk areas, supplied by FAP-20.

Apart from the main inlet, peripheral inlet and Lohajang outlet structures, the designed internal water control structures have been included in the model to be able to maintain the required water levels in the chawks (see Table 5.4).

For simulation of the operation of the main inlet and the combined weir/gated structures in the model, a modified controlled structure module has been included in MIKE11. The structure operation can be controlled by either an upstream or a downstream water level. It is also possible to write a user defined control system within the module.

The general operation rules being tested for different structures in the Tangail compartment are given below:

<u>Type</u>	<u>Operation</u>
main inlet	fully open until mid-July, then, when the water level downstream exceeds 11m + PWD, the first gate of the 3 inner vents will be lowered till the sill and to control the water level downstream, the second gate must be used together with the 2 outer vents which stay open (sill level at 11m + PWD); the 2 outer vents will be closed depending on the flow velocity / water level difference.
peripheral inlet	fully open until mid-July and after monsoon, during monsoon to be operated depending on the downstream water level and target level of sub-compartment.
controlled inlet/ outlet between Lohajang and sub compartments	functioning as in- or outlet structure depending on between Lohajang the water levels in the compartment and the Lohajang river, during monsoon open when drainage is possible and depending on target level of compartment, else closed and open after monsoon.
controlled structure	low section with regulator (based on pre-monsoon discharge

between chawks	requirements) closed during monsoon, the weir and SC's section has a fixed weir level based on the required water level in the upstream part during monsoon.

5.6 Future work programme.

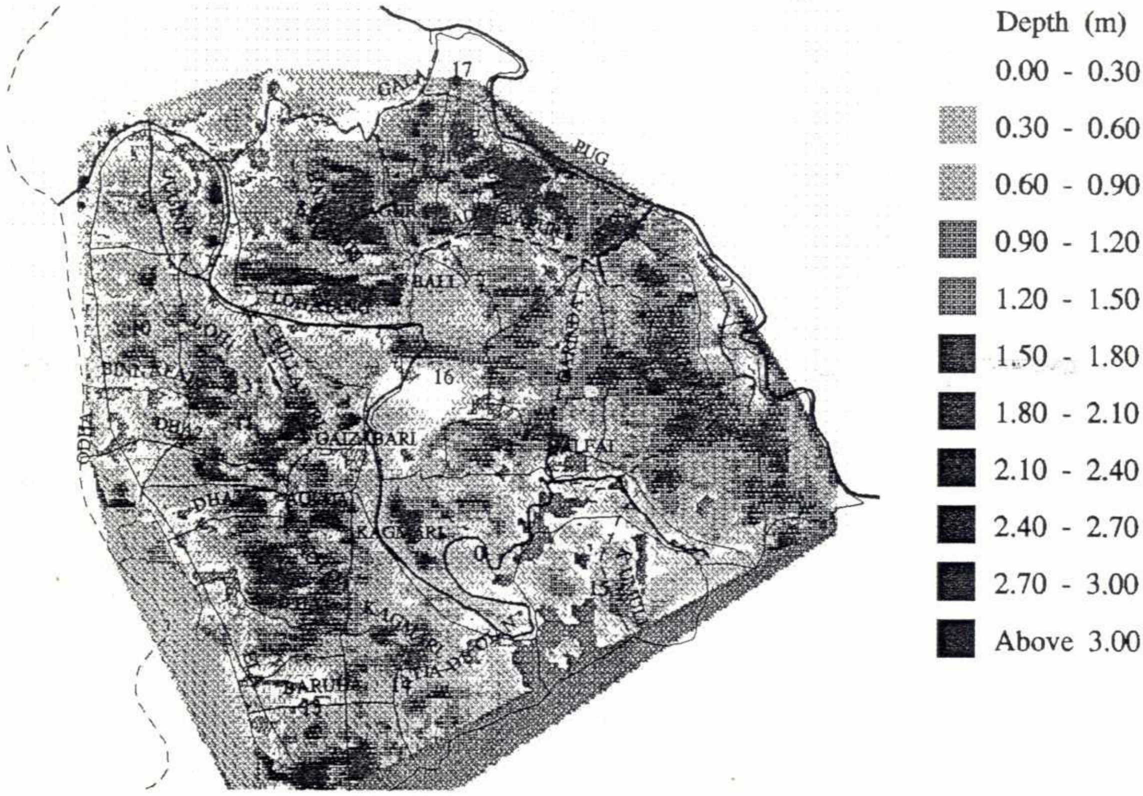
The calibration of the TCM will be finalized using 1993 data . The model will also be verified for the years 1991 and 1992. The detailed schematization of sub-compartments 9, 10 and 11 will be completed for the proposed "with structures" situation and structure operation will be tested.

After the North Central Region Mode l(NCRM) has been calibrated and verified, the Tangail Compartment model will be run for historical years. The NCRM is needed to generate the historical boundary conditions for the TCM. It is also proposed to test a phased construction of the structures using the model. Again, the historical simulation approach will be to generate statistics and identify any extreme events. A long term structure operation guideline will be prepared based on the historical model simulations. Applicability of an optimization scheme is also being investigated at the present time.

Finally, in collaboration with the sectoral experts (agriculture, fisheries, etc.) of FAP20, attempts will be made to produce flood impact maps to assess the consequences of various development and water management scenarios.

Flood Depth Map
Tangail Compartment

Figure 5.4



Flood Depth Map (Sept. 04, 1993)

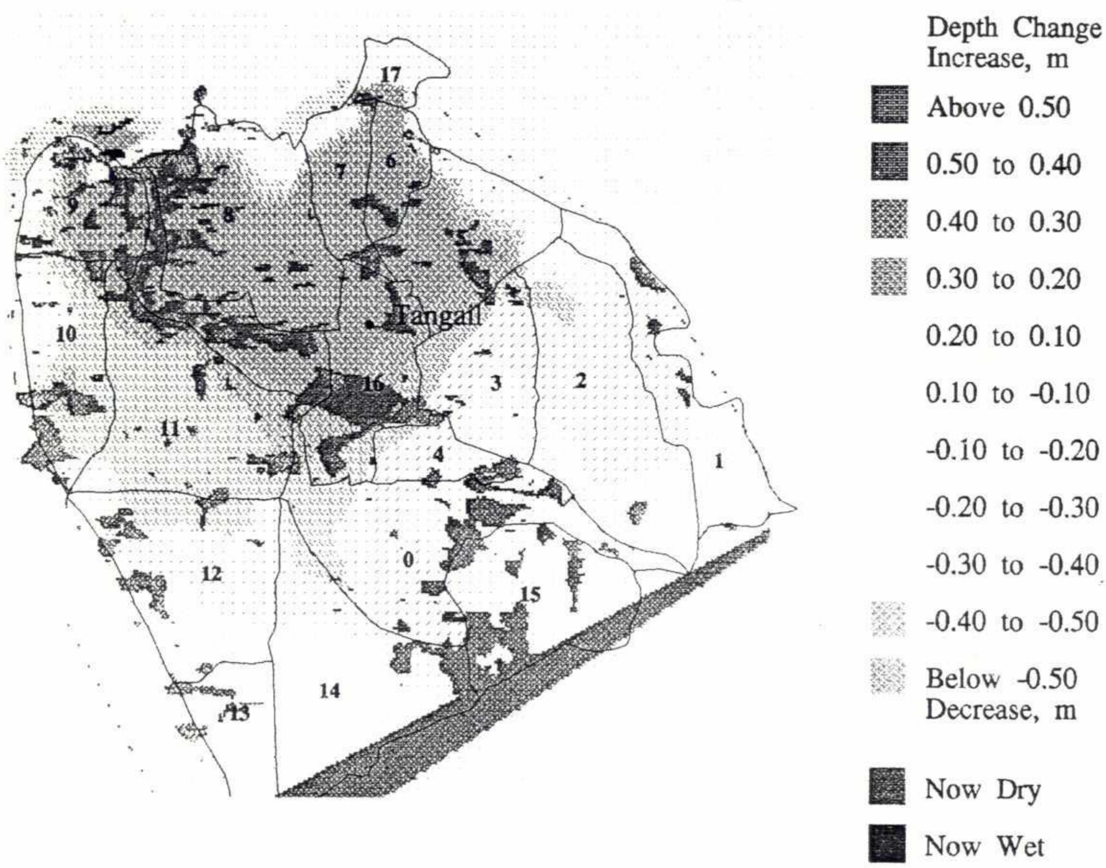
Figure 5.5

Flood Depth Map with Peripheral Structures (Sept. 04, 1993)

Impact Map

Tangail Compartment

Figure 5.6



Change in Flood Depth (With & Without Control)

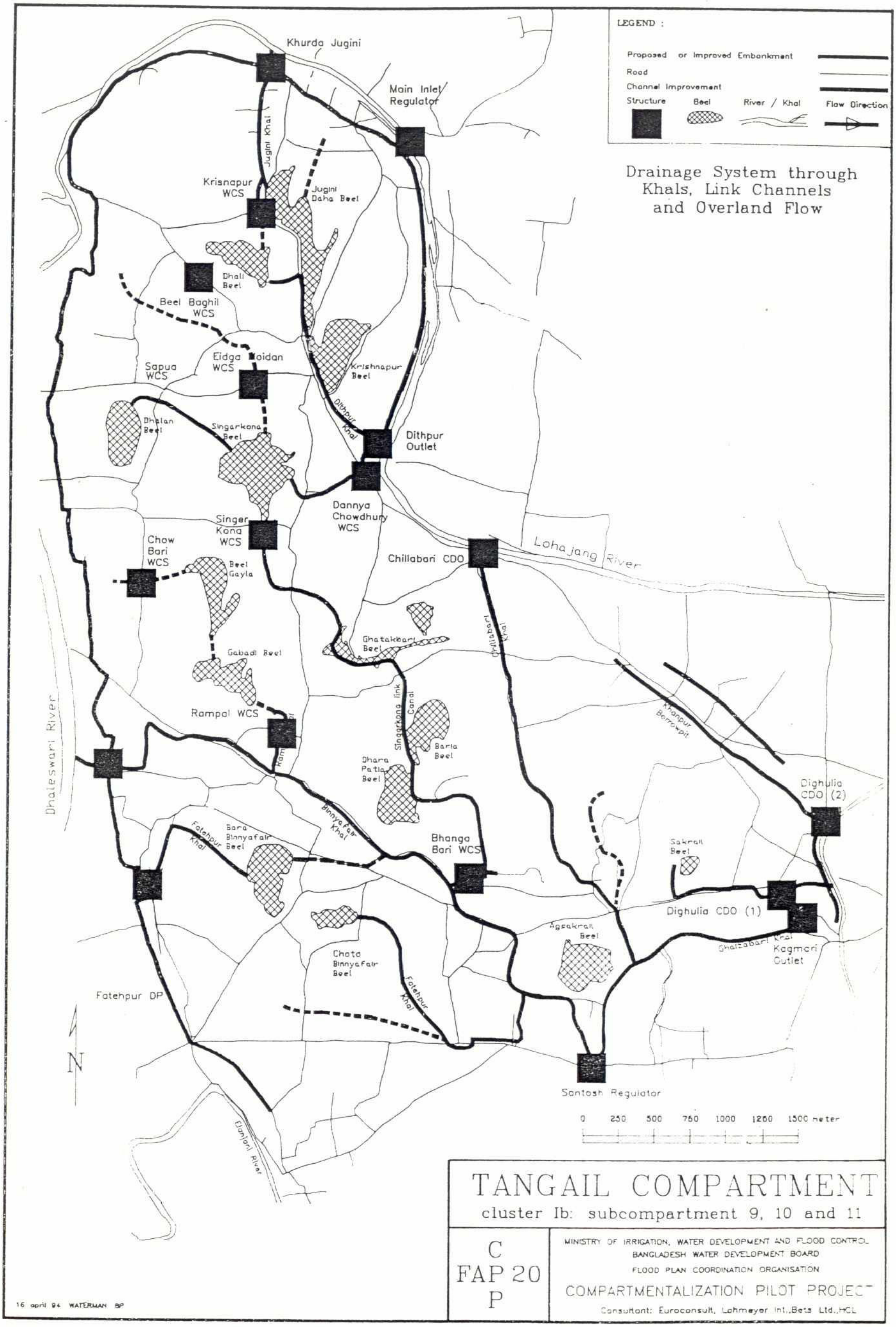


Figure 5.7 Detailed Scheme of the TCM Cluster 1 Model

Table 5.2 Cross-reference list of TCM-Cluster 1 channels (WMP-94).

Channel	at km	connected with	at km	connected with	at km	Boundary	Gauge
BINNAFAIR	0.00	ODHA	26.00				G21
BINNAFAIR	3.00	SINGARKONA	6.50				
BINNAFAIR	4.70	FATEHPUR	3.50				
BINNAFAIR	5.30	GAIZABARI	0.00	AOLOA	3.70		G22
CHILLABARI	0.00	LOHAJANG	7.90				
CHILLABARI	3.40	GAIZABARI	0.80				
DANNYA	0.00					Q=0	
DANNYA	1.50	SINGARKONA	0.90				
DANNAY	2.35	LOHAJANG	7.00				G36
FATEHPUR	0.00	ODHA	27.00				
FATEHPUR	3.50	BINNAFAIR	4.70				
GAIZABARI	0.00	BINNAFAIR	5.30	AOLOA	3.70		G22
GAIZABARI	0.80	CHILLABARI	3.40				
GAIZABARI	2.35	LOHAJANG	13.00				G03
JUGINI	0.00	LOHAJANG	3.00				
JUGINI	1.80	MAHJI	1.20				
JUGINI	3.30	LOHAJANG	6.53				
MAHJI	0.00					Q=0	
MAHJI	1.20	JUGINI	1.80				
RAMPAL	0.00	LOHAJANG				Q=0	
RAMPAL	2.20	BINNAFAIR	1.20				
SINGARKONA	0.00					Q=0	
SINGARKONA	0.90	DANNYA	1.50				(G24)
SINGARKONA	5.20	BINNAFAIR	3.00				

G(xx): gauge nearby in khal or floodplain.

Table 5.3: Operational water levels (m) at chawks of SC 9, 10 & 11 of Tangail compartment under proposed water management system

Chawks	Premonsoon*		Onset of monsoon*					Remarks
	Water level (maximum)	Lowest field level	General Objective	Optimum	Maximum	Minimum	Av. field level	
Sub-Compartment 9								
9A	11.40	10.70	Ext.HYV	11.50	11.70	11.20	11.25	
9B	10.45	9.75	Ext LV**	11.10	11.30	10.00	10.50	Beel #
9C	11.70	11.00	Ext.HYV	11.50	11.70	11.20	11.20	
9D	11.25	10.25	Ext.HYV	11.30	11.50	10.50	11.00	Beel #
9E	10.75	10.05	Ext.HYV	11.00	11.25	10.05	10.70	Beel #
9F	11.15	10.45	Ext.HYV	11.25	11.50	10.90	10.95	
9G	11.10	10.40	Ext.HYV	11.00	11.20	10.80	10.70	
9H	10.95	10.25	Ext.HYV	11.00	11.20	10.80	10.70	
9J	11.50	10.80	Ext.HYV	10.90	11.00	10.75	10.60	
9K(=11A)	11.20	10.50	Intr.HYV	10.80	11.00	10.50	10.50	
Sub-Compartment 10								
10A	10.40	9.70	Ext.HYV	10.80	11.00	10.00	10.50	Beel
10B	11.25	10.55	Ext.HYV	11.10	11.20	10.70	10.80	
10C	11.60	10.90	Ext.HYV	11.25	11.50	11.00	11.00	
10D	10.20	9.50	Ext.HYV	10.50	10.70	9.60	10.20	Beel
10E	-		Ext.HYV	11.10	11.20	10.90	10.80	
10F	-		Ext.HYV	11.00	11.20	10.90	10.70	
10G	-		Intr.HYV	10.50	10.70	10.20	10.20	
10H	10.70	10.00	Ext.HYV	10.50	10.70	10.00	10.20	Beel
10J	11.35	10.65	Ext.HYV	11.00	11.20	10.80	10.70	
Sub-Compartment 11								
11B	10.35	9.65	Ext.HYV	10.25	10.50	9.75	9.95	Beel #
11C			Ext.HYV	10.50	10.70	10.20	10.20	
11D	10.45	9.75	Ext.HYV	10.50	10.70	9.50	10.20	Beel #
11E	10.35	9.65	Ext.HYV	10.50	10.70	9.70	10.20	
11F	10.25	9.55	Ext.HYV	10.30	10.50	10.00	10.00	
11G	10.00	9.30	Ext.HYV	10.00	10.25	9.25	9.50	Beel #
11H	10.05	9.35	Ext.HYV	10.50	10.70	10.30	10.20	
11J	9.55	8.85	Intr.LV**	10.00	10.20	9.00	9.50	
11K	-		Ext.HYV	10.50	10.70	10.30	10.20	
11L	10.00	9.30	Intr.LV**	10.50	11.00	9.50	10.20	Beel
11M	10.50	9.80	Ext.HYV	11.00	11.20	10.20	10.70	
11N	9.60	8.90	Ext.HYV	10.30	10.50	9.50	10.30	
11P	10.00	9.30	Intr.LV**	10.30	10.50	9.50	9.75	
11Q	10.30	9.60	Intr.HYV	10.30	10.50	9.50	10.00	
11R	9.95	9.25	Intr.HYV	10.30	10.50	9.25	10.00	Beel
11S	10.30	9.60	Intr.HYV	10.25	10.50	9.50	10.00	
11T	10.05	9.35	Intr.HYV	10.00	10.20	9.80	9.70	
11U	10.10	9.40	Intr.HYV	9.80	10.00	9.70	9.50	

[shaded] Chawks with probability of damage during harvesting of HYV Boro. Starting from the first rain of the season, inlets to these chawks should be closed and outlet open so that water can be drained to adjacent chawks to the limit of maximum premonsoon water level and subsequently to nearest drainage system.

\- As HYV Boro is not grown in these chawks, premonsoon water level is not required.

* Premonsoon (maximum) : Water level during 1st week of May. Water level at individual chawk should be within this maximum limit.
Onset of monsoon: Water level during mid July. This period coincides with transplanting of HYV T. Aman.

\# Chawks with beels should never be drained beyond minimum water level shown during monsoon.

** In places where extension of LVs is general objective, late transplanted HYVs, like BR22 and 23 can easily be introduced. The only water management requirement is early drainage in mid september

Table 5.4 Structures included in the model of TCM-Cluster 1 (WMP-94).

Structure	Channel	at km	Weir (m)	Sill level (m+PWD)	Gate (m)	Sill level (m+PWD)
Jugini inlet	Jugini	0.0			1.5x2.4	10.0
Krishnapur WCS	Jugini	1.2	1.5x2.95	11.55	1.5x1.8	9.75
Ditpur regulator	Jugini	3.3	2.0x1.0 (2x)	10.9	0.9x0.9	9.45
Eidgah Maidam WCS	Dannya	1.0	0.9x1.2	10.45	0.9x1.2	9.25
Dannya Chowdury CDO	Dannya	2.35			0.9 dia	8.7
Sapua WCS	Singarkona	0.2			0.6 dia	8.7
Singarkona outlet	Singarkona	1.2	1.5x1.83	10.58	1.5x1.83	8.75
Bangabari WCS	Singarkona	5.2	1.5x1.83	10.43	1.5x1.83	8.6
Chowbari WCS	Rampal	0.25			0.6 dia	9.5
Rampal WCS	Rampal	1.9	1.5x2.7	10.8	1.5x1.8	9.0
Binnafair regulator	Binnafair	0.0			0.9 dia	9.19
Santosh weir/CDO	Aoloa	3.74	1.5x5.5 (3x)	10.0	1.5x2.0 (3x)	8.0
Fatehpur regulator	Fatehpur	0.0			0.9 dia	9.19
Chillabari CDO	Chillabari	0.0			0.9 dia	8.1
Kagmari regulator	Gaizabari	2.35	1.5x4.6 (2x)	8.85	1.5x0.85(2x)	8.0

WCS: Water Control Section
CDO: Contolled Drainage Outlet

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/8/ FAP5: South East Region Water Resources Development Programme. Interim Report. Volume II. Annex V. Hydrology and Water Modelling. November 1991.

/9/ Surface Water Modelling Centre. North Central Regional Model. Full Calibration and Verification Report. December 1993.

/10/ FAP25: Flood Modelling and Management. FMM Interim Report -I . January 1994.

/11/ FAP25: Flood Modelling and Management. Coordination Advisory team (CAT).Fifth Mission Report. January 1994.

APPENDIX

Comment and Replies

Comments on Draft Interim Report-II,
Flood Management Model (May 1994)

General Comments:

The report is informative and well organized. However, the following points may be mentioned:

One of the objectives of FMM is to assist in mitigation of flood damages. In this regard a major use of the FMM will be assessment of agricultural damage immediately after a flood in order to chalk out a viable agricultural rehabilitation plan. Flood damage assessment has been addressed in Section 3.7.2 (Page 13). According to the proposed method, flood damage will be assessed based on the flood depth exceeding a critical depth. This method is adequate for planning purpose. For mitigating purposes, the method is however not sufficient (!).

During or immediately after a flood, reliable estimate of flood depth is difficult to gather. In such situations, spaceborne images has the potential to guide to adequate damage assessment. If the proposed methodology and interpretation of spaceborne images can be integrated through GIS, this will provide a better tool for planning of agricultural rehabilitation immediately after frequently occurring floods.

1. Page 11: Table 3.1

   Start time should not be fixed on June 1, 1993. Provision should be kept for earlier start time. Likewise provision for end time should be extended till September/October.

2. Page 13: Para 3.7.2

   This paragraph on Flood Damage Mapping does not provide an accurate picture of how this would be done. Data on cropping pattern with mention of crop varieties should be collected. Submergence tolerance limit of each crop by growth stage is the key information needed for assessing flood damage. The flood depth map should be superimposed on the submergence tolerance limit data of the growth stage of the crop being grown in the field at the time of occurrence of flood to identify area where crops are damaged by flood.

3. Page 13: Figure 3.2

   What are these crops? Whatever be the crop, the critical depth can not be in meter (m). This has to be in cm or mm.

4. Page 13, Article 3.7.2

Flood Damage mapping

It is a fact that the duration of flood is the basis of identifying the flood damage as has been pointed out in the report. But duration is one of the criteria. Other criteria like water quality, cropping pattern and stage of maturity of plants are to be considered. In BWDB design criteria, hundred percent damage is considered for inundation beyond 72 hrs. for a depth of inundation of 30 cm or more. But for lesser duration damage occurs partially. As such, it is suggested to elaborate this article. Assessment of damage should be supported by methodology outlining the concept.

5. Page 13, Article 3.8 and Fig. 3.4

Flooded area statistics represented in tabular form showing MPO classification may create confusion. MPO land type classification depends on average depth of inundation. In FMM output variable depths of inundation which change from time to time are available. The concept of changing pattern as an output of FMM should be highlighted.

6. This report has been prepared mainly to report the status of work progress during the past 4 months (as mentioned in Art. 1.2 of the report).

   It is felt that a clarification may be given in the future reports of FMM about the activities those are done under FAP25. SWMC, FAP19 and to some extent FAP24 so that confusion does not arise.

7. The MIKE11-GIS specially for FAP25 are the main data base tool. The source of the main data base (WARPO/SWMC) and its subsequent utilization by different FAP need to be stated.

   Page-4, para (d) - FAP 10 specially for flood forecasting using the output of FAP25 which a schematic diagram can explain this.

8. Page 5,6,7 - the work program and the schedules of inputs should indicate the original input as per TOR and approved agreement.

9. The output for FAP20 from FAP25 (Modelling) may be prepared separately and which would be a part of FAP20 study also.

10. Page 8, Art 3.1 4th para and page 13, Art 3.9 - a draft of the MIKE11-GIS workbook has not been submitted with this report as (mentioned).

11. Page 17, Art 4.2.1 para 3 - It is not clear whether a re-structured MIKE11 hydro-dynamic model has been established which is capable of addressing the particular needs of the flood plain modelling.

12. It is understood that a trial rand of GM-FMM on flood forecasting is possible to carry out during the present monsoon at FF&WC. In this respect it can be mentioned here that the prediction of area inundation is based on MIKE11 output and the present version of MIKE11 is not suitable for flash-flood and tidal-flow simulation as understood from the past forecasting result in FF&WC. Forecasting of flash flood with present MIKE11 FF has been found far beyond the actual level which has been mentioned several times before. In the case separate model may be introduced for area inundation forecasting in the flash flood prone area.

13. The flood damage mapping and the statistics as furnished under an example provides only an outlook to the sector specialists. This should be developed more so as to obtain a complete damage maps of different levels of utility and impact on such damages can be assessed to the desired degree of accuracy.

14. Pages 25 and 26

The y-axes of figures for Nayerhat, Savar and Mirzapore have been inflated in the case of SWMC Basic Model compared to FMM model. Such comparisons display as exaggeration of inaccuracies in SWMC Basic Model Simulations.

15. Page - 39, last para:

Figure 5.6 shows impacts of proposed peripheral structures upon flood depths. An annual report of CPP (FAP20) dated December 1993 and a status report of CPP (FAP20) dated June 1994 also describe impacts of peripheral structures upon adjacent areas to Tangail compartment. They show water level rise of 0.4 to 0.5m in the area just upstream of the compartment (see pages 37 and 38 of the annual report as well as of the status report). They also document details of other impacts. These impacts have been assessed from simulation results of FMM. Are these results are from same model simulations as in the case of Fig. 5.6. If yes, consistency between results of annual/status reports (FAP20) and interim report-II (FAP25) is to be examined. If not, how the results in annual/status reports have been obtained should be discussed. It has been mentioned that model results would be used in the investigation fo refuge sites in the CPP.

16. Planning of the Tangail Compartment is based on WL of 1991 as a base case, It could be better if the comparison is made for 1991 instead of 1993, so that the original planning aspects can be verified. In addition, it is seen that in same areas, the WL will rise in case of with project situation, reasons may be explained.

Assumption of with project situation can be stated.

17. Clause 5.5

A start has been made with a detailed schematization of the cluster of Sc. 9,10 and 11................to develop structure operation guidelines.

When the structures operation guideline for the whole compartment will be completed and whether within schedule time?

18. <u>In page 3, clause 2.1:</u>

It is a stated that the development of the Tangail Compartment FMM has been completed. Applications are being carried out.

Whereas in page 39, clause 5.3 stated that due to change in priority of the work tasks, the calibration has not been finalized. It is planned to continue with the calibration work after carrying out................

What were the priories needs to be stated. How the total tasks will be complete in schedule time needs to be explained. In clause 5.4.3 Flood depth maps and flood depth difference for the 1993 simulated as a base situation and shows in fig. 5.4, 5.5 and 5.6.

19. <u>Art. 4.5, Demonstration Runs</u>

Page 31, para 1, It has been stated that application exercise will consist of embankment along main water course. Instead of main water course it should be stated "along Jamuna and other main water courses". Demonstration done "with" and "without" embankment along the Jamuna will indicate the effect of embankment.

20. <u>General Comment</u>

It can be seen that while the MIKE11-GIS interface has been fully developed, the interpretation software necessary to facilitate various types of impact assessment has not yet been developed. It is essential that these developments are completed without interruption, so that the full Flood Management Modelling tool becomes available soon. It is clear that these further developments will need to be carried on beyond the closure of the project in October'94. The proposed transfer of FMM to SWMC should be provided with resources to complete this task.

<u>Comments by CFD Delegate</u>

The NCR/FMM section abundantly states that this model is a demonstration model. This Embassy funded extra topographical surveys and 1993 monsoon hydrological measurements to help the demonstration, and as well to permit progress in the accuracy. We are now interested in:

- verification of the model on the basis of 1993 monsoon data; will this be carried out by FAP25?

- definition of the additional topographic surveys needed for a better representation of the flood recession period, and for future work by the users of the regional model.

The difference between SWMC former model and the FMM is already evident and this will be useful in adjusting options and impacts of the NCR development plan.

The observation that boundary rivers have to be included in future FMM type models in important and should be stressed for future users (i.e. FAP3.1 and 3.2).

- color figures should be provided in the final version (for understanding fig. 3.1 to 4 and 4.8 4,9).

FAP25: Flood Modelling and Management
Flood Management Model

Reply to Comments

General Comments:

The spaceborne Radar images cannot give depths and therefore cannot be used in damage assessment. However, use of such images for verifying simulated flood extent is being investigated in collaboration with FAP19.

1. The start and end times are flexible. "June 1, 1993" is only a typical value used in the illustrative example.

2. The procedure described exactly in the comment has been used in GIS analysis. The write up will be revised.

3. This is a hypothetical example. The critical depth should be in cm.

4. Flood Damage Mapping: The crop damage mapping example provided in the report illustrates the use of flood duration maps. The concept of critical depths for different crops at different crop growth stages takes care of other criteria. It is agreed that water quality is a criteria, but is beyond the scope of the present study.

5. The MPO flood phases are used only to indicate depth classes. Flooded area statistics can be produced using average depths of inundation.

6. The flood management models developed by FAP25 are based on the digital elevation models developed by FAP19 and the MIKE11 models developed by SWMC and FAP20. FAP24's data are used by SWMC for the General Model. SWMC's models use data from various sources such as BWDB, WARPO, BIWTA etc.

7. A Schematic diagram for using the FMM by FAP10 will be provided in the final report.

8. The total staff allocation is as per TOR and approved agreement. However, some internal adjustments have been made to meet the project objectives in a way so that project cost remains unchanged.

9. The output for FAP20 will be reported as part C of Vol. 2 in the Final Report.

10. The MIKE11-GIS workbook has been renamed as Training Manual and it will be submitted with the final report.

11. A restructured MIKE11 hydrodynamic model for the western part of the North Central region has been established, which is capable of addressing the particular needs of flood plain modelling.

12. The FMM methodology developed by FAP25 can be used for mapping flash floods. It is the hydrodynamic modelling part that needs to be further developed to take care of the flash floods and tidal floods.

13. Sectoral specialists can use the FMM produced flood maps for complete damage mapping.

14. The different scales for y-axis in figures 4.5 and 4.6 are noted. They will be corrected.

15. The FAP25 outputs are based on test runs of Tangail FMM. The updated flood maps are now produced and the application results will be presented in the Final Report. It is expected that FAP20 will incorporate the latest model outputs in their future applications.

16. Presentation of 1993 flood maps are for illustration only. Model calibration was done on 1993 because more observations are available for that year. The model can be used for any year for actual analysis.

    The subcompartment water levels have been roughly estimated, which may be too high. However, it is still possible that water levels in the with-project situation will be higher at some places due to structure control (water retention).

17. Completion of the structure operation guideline for the whole compartment is beyond the scope of work of FAP25. FAP25 will provide FMM tools and it is expected that FAP20 will continue to work on the model for this purpose.

18. Now, both the tasks, Development of Tangail compartment FMM and calibration of the MIKE11 model, are complete.

19. Demonstration runs of the NCR FMM will consist of embankments along the main water courses which form the main elements of demonstration compartments in the region.

20. FAP25 have submitted a proposal for continuation of the development activities after the transfer of FMM to SWMC.

<u>Comments by CFD Delegate</u>

1. The monsoon data of 1993 have been used for model calibration and verification. The topographical data were used in restructuring the NCR (SWMC) model to more appropriately model the floodplains.

2. Color figures will be provided in the final report.