BANGLADESH FLOOD ACTION PLAN

Ministry of Water Resources

Flood Plan Coordination Organization (FPCO)

(3)

Completion Report

A Summary of Activities from 1991-1995

June 1995

Prepared by

Geographic Information System (GIS)

FAP 19

ISPAN

IRRIGATION SUPPORT PROJECT FOR ASIA AND THE NEAR EAST

Sponsored by the U.S. Agency for International Development

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ACRONYMS

ALC	ARC/INFO Learning Center
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Center for Advanced Studies
BCL	Bangladesh Consultants Ltd.
BMD	Bangladesh Meteorological Department
BWDB	Bangladesh Water Development Board
BUET	Bangladesh University of Engineering & Technology
CARE	Cooperation of American Relief Everywhere
CD	Compact Disk
CDA	Chittagong Development Authority
CDP	Crop Diversification Program
CPP	Compartmentalization Pilot Project
DCMU	Disaster Coordination and Monitoring Unit
DDC	Development Design Consultants Ltd.
DEM	Digital Elevation Model
DMB	Disaster Management Bureau
DOE	Department of Environment
DPC	Development Planners & Consultants
EIA	Environmental Impact Assessment
ESRI	Environmental Systems Research Institute
FAP	Flood Action Plan
FPCO	Flood Plan Coordination Organization
GIS	Geographic Information System
GOB	Government of Bangladesh
GPS	Global Positioning System
ICDDRB	International Center for Diarrheal Diseases & Research, Bangladesh
ICIMOD	International Center for Integrated Mountain Development
IFFD	Integrated Food For Development
IMED	Implementation, Monitoring and Evaluation Division of Planning Commission
ISPAN	Irrigation Support Project for Asia and the Near East
LGED	Local Government Engineering Department
MoIWDFC	Ministry of Irrigation, Water Development & Flood Control
MOWR	Ministry of Water Resources
MPO	Master Plan Organization
MSS	Multi Spectral Scanner
NGO	Non Governmental Organization
NMIDP	National Minor Irrigation Development Project
SAR	Synthetic Aperture Radar
SOB	Survey of Bangladesh
SPARRSO	Bangladesh Space Research & Remote Sensing Organization
SRDI	Soil Resources Development Institute
SWMC	Surface Water Modeling Center
TM	Thematic Mapper
WARPO	Water Resources Planning Organization

PREFACE

This completion report is a summary of activities and outputs of FAP 19 since its inception in April 1991 through the last phase which ended in June 1995. The study provided a geographic information system (GIS) and related technologies for supporting the Flood Action Plan which resulted in a variety of spatial databases and analyses for water resources management and planning. These activities are summarized in this completion report. Those interested in further information on the various activities of FAP 19 may consult the specific reports, technical notes, training manuals, and archive documents which are referenced in this completion report.

1. INTRODUCTION

1.1 The Flood Action Plan

Following the severe floods of 1987 and 1988 a Flood Action Plan (FAP) was developed by the Government of Bangladesh (GOB). The GOB requested the World Bank to coordinate the Plan's efforts along with the Flood Plan Coordination Organization (FPCO), a special office under the Ministry of Water Resources. The Flood Action Plan is a multi-donor funded program originally comprised of 26 study components and pilot projects, consisting of local and regional studies of water control measures, such as embankments and compartments, as well as nonstructural measures like early warning, flood proofing and flood response.

The purpose of the Flood Action Plan is "to investigate options for reducing damage caused by floods in Bangladesh, to set the foundations of a long-term program to meet Bangladesh's objective of achieving a permanent and comprehensive solution to flood control in reducing the risks associated with economic activity on the floodplains, and increase the economic growth rate of the country".

1.2 Project FAP 19

Flood Action Plan 19, a study component with a mandate to establish a geographic information system (GIS) to serve the information needs of other FAP activities, has assisted those within FAP in planning and management. The first phase of the activity was initiated in April of 1991 and completed in October of 1993. The second phase started in October 1993 and was completed in June 1995.

A GIS is a computer-based technology for capturing, recording, manipulating, analyzing, and displaying georeferenced data such as digital maps and satellite images.

Because of its considerable and diverse application potentials, this powerful tool is being widely used for planning and monitoring purposes throughout the world. A key feature of GIS is that large and diverse data sets can be linked together through common spatial reference and can be arranged in separate thematic layers, such as elevation, soil type, ground water level, crop cultivation, population density and average income, these data can be combined and analyzed to suit requirements.

The major use of a GIS is to provide digital mapping and spatial analyses specific to the requirements of individual users. Different users may generate different map analyses and products using the same sets of data.

FAP 19 has created a microcomputer-based geographic information system that serves various application projects and pilot studies. As part of these projects and in support of other FAP studies, FAP 19 has developed digital databases and map products that demonstrate the application of this technology in Bangladesh, and are being used, especially in the water resources sector. These applications include interfacing with hydrologic and hydraulic models through digital terrain modeling; mapping and analysis for environmental impact assessments; landscape change monitoring to characterize fluvial processes and river morphology; mapping and analysis for design and management of flood compartments; and the creation of a national database for planning and management.

2. EXPECTED RESULTS

Accomplishments of FAP 19 are substantially in excess of what was originally planned. Examples of these are the number of organizations having received technical support by the project and the series of technical notes produced to assist planners.

2.1 Scope of Work

FAP 19 activities have included comprehensive GIS application projects, demonstrations and pilot studies for implementation on a larger scale by FAP or other development projects, and extensive training for the staff of FAP 19 and other development institutions.

The output from FAP 19 includes not only reports, maps, images, and digital databases, but also support to other FAP programs, training of personnel, and efforts specifically designed for building the overall GIS capability in Bangladesh.

2.2 Objectives

FAP 19 was designed to demonstrate, test and develop applications of GIS for activities under the Flood Action Plan. The objectives of FAP 19 as described in the Terms of Reference are outlined below:

- Provide a GIS facility to assist in planning and managing geographic information for the FAP;
- Assist FPCO in establishing a GIS network to serve the various FAP users;
- Promote and establish standardized data protocols and database formats among the various GISs in FAP;
- Provide on-the-job training in GIS technology to FPCO and other government and non-government organizations in support of FAP activities;
- Promote unrestricted access to water resources management and planning information for legitimate users.

3. ACTIVITIES

The tasks and activities for meeting the objectives and fulfilling the scope of work are discussed below.

3.1 Development of the FAP 19 Resources

One of the primary tasks of FAP 19 was to build up GIS resources through professional development, acquisition of data, and establishment of a GIS facility including hardware and software.

3.1.1 Professional Development

FAP 19 recruited and trained 17 professional local staff ranging from senior to mid and junior level. Staff backgrounds included engineering, geography, mathematical modeling and computer science. Staff designation is presented in Appendix A.

One expatriate resident GIS team leader has been employed since the project's inception. Other expatriate experts and consultants were hired for short-term inputs in speciality areas including digital elevation modeling, map projections, GIS institutional aspects, global positioning system, hydrodynamic modeling, radar technology, image processing and floodplain sedimentation modeling (Appendix B).

3.1.2 GIS Hardware and Software

FAP 19's GIS facility was originally designed in 1991. Design criteria were developed to ensure that FAP 19 objectives were met and for compatibility with existing GISs in Bangladesh. Specifically, the following design criteria were decided upon for selection and installation of the GIS system:

- systems were to be micro-computer based;
- system should contain both raster and vector capabilities;

- digital terrain and elevation data modeling capability should be included;
- data format should be similar with other GISs in Bangladesh;
- capable of running widely used, user-oriented GIS software.

The FAP 19 hardware is entirely PC-based. The hardware system consists of eleven 486 and six 386 microcomputers with SVGA monitors, two 20" RGB monitors and two 32 bit Imagraph image processors,. The total hard drive capacity consists of 8.5 gigabytes with an average of. Other mass storage systems include five Colorado Memory System tape backup devices, a 9-track Cipher 6250bpi tape drive, and a CD-ROM write system.

The peripherals consist of Calcomp digitizing tables, Calcomp 8-pen plotter, Tektronix color printers, a Laserjet printer, dot-matrix printers and a scanner. The local area network consists of ten nodes of Lantastic NE2000. In addition, there are three Magellan global positioning system receivers (GPSs).

Some of the hardware was purchased in the U.S. and shipped to Bangladesh. Some of it was leased locally. The list of hardware and software resources of FAP 19/ISPAN is shown in Appendix C.

The GIS software all originates from the U.S. Over a span of four years, FAP 19 acquired software resources not only in vector and raster GIS, but also a number of operating systems, graphics packages, computer and project management tools, and a local area network.

FAP 19 has acquired a total of 10 pcARC/INFO licenses for project use and another 6 licenses for training purposes. In addition, a total of 6 ERDAS licenses have been acquired. Specific vector software in use includes pcARC/INFO, pcTIN, and ARCVIEW2. The raster packages are ERDAS, ERDAS Imagine, Earthview, IDRISI, Surfer, IDA, and IMAP 1.28.

The operating systems are DOS, Windows, and Windows NT. The application packages are Dbase IV, QAPlus, Quattro Pro, Lotus 123, WordPerfect DOS and Windows. The graphics packages include CorelDraw, Adobe Photoshop and Deluxe Paint. The utilities include Superprint, Lantastic, PCTools, Norton Utilities, Norton Anti-virus, and AMI Diagnostics. (See Appendix C for further details).

3.1.3 Data Resources

Over the years FAP 19 has built a substantial data resource gathered from a variety of sources including satellite imagery, aerial photographs, maps and data from organizations such as SOB, BWDB, SWMC, MPO, BARC, LGED, SPARRSO, SRDI, and BBS. These data are stored in large format map files and on digital tape and CD.

3.2 GIS Applications and Support Projects

The first objective of FAP 19 was to provide a GIS facility to assist in the planning and management of geographic information for the Flood Action Plan. This objective was met by implementing various application projects to support FAP projects and other programs within the broader objectives of the FAP as shown in Table 1. The relevance and achievements of each of these application and support projects are discussed below.

3.2.1 Digital Elevation Modeling and Spatial Interface for Hydrologic/Hydraulic Models

Over the past ten years, a series of hydrodynamic models has been developed for Bangladesh, which compute water levels at specified stations or points along watercourses. Using GIS analysis, FAP 19 developed procedures for converting the water elevations into maps showing the depths of flooding in rivers as well as the extent and depth on the floodplains. For the first time in Bangladesh,

through this project, the consultants in the water resources sector visualized the flood model results using GIS.

The GIS techniques developed under this project make extensive use of surface modeling through the creation of digital elevation models for both the land and flood water surfaces. The intersection of the two surfaces defined the potentially flooded area and depth of flooding. The advantage of this technique is that flood model results can be portrayed graphically and flood depth maps can be integrated digitally with other GIS themes for assessing the impacts of alternative scenarios. Figure 1 illustrates the flood model results of the Tangail component. Data, methodologies and results provided a basis for

Table 1 FAP 19 Application and Pilot Studies

Studies	Cooperators
Digital Elevation Modeling and Spatial Interface for Hydrologic/Hydraulic Models	FAPs 3, 4, 20, 25
Tangail Area EIA Case Study	FAPs 16, 20
Charland Study	FAP 16
River Channel Morphology	FAPs 1, 21/22, SPARRSO
Sedimentation Study	FAP 16
Bhelumia-Bheduria EIA Case Study	FAP 16
Disaster Management Study	DCMU, CARE, DDC
Satellite-Based Radar for Flood Monitoring	FAPs 17, 20, 25; SWMC, SPARRSO
Applications for IFFD	CARE, LGED
Flood Forecasting and Warning	BWDB (FFWD)
National Database for Land and Water Resources Planning	BWDB, SWMC, BARC

the development of the Flood Management Model (FAP 25) to construct flood depth and extent maps using DEM.

Detailed digital elevation models (DEMs) of the North Central Region (FAP 3 study area) were constructed and the MIKE 11 model was linked with the flood cells of FAP 3. For the Southwest Water Management Study (FAP 4), semi-detail DEMs were used in generating flood cells. FAP 19 also generated a flood depth extent map for 35cm sea level rise for FAP 4 study area (FAP 19, 1993a, 1993b, 1993c). Also, the flood mapping techniques played an important role in planning and designing of water control structures within the Tangail CPP area. This project was carried out for FAP 20 to test the use of GIS in converting DEMs into flood depth classification and extent maps using MIKE11 outputs (FAP 19. 1993d, 1993e).

3.2.2 Tangail Area EIA Case Study

GIS was used as a mapping and analytical tool for the EIA case study conducted by FAP 16 in the Tangail CPP. FAP 20 and FAP 16 had a common interest in population density as well as in cropping patterns, fisheries and other themes. The EIA Case Study of the Tangail Area (FAP 16/19, 1992) focused on calculating the distribution of flood inundation scenarios (land types) for "with project" and "without project" situations as illustrated in Figure 1.

The MIKE11 model was used by FAP 20 to calculate flood water level from tabular data under various scenarios, to assist in estimation of project effects. With GIS surfacing techniques used by FAP 19, water surface was generated from flood model results and the intersection with DEM produced digital map of inundation depth and extent. For the first time the human interventions and their effects on the environment could be visualized in magnitude and space (FAP 19, 1992b).

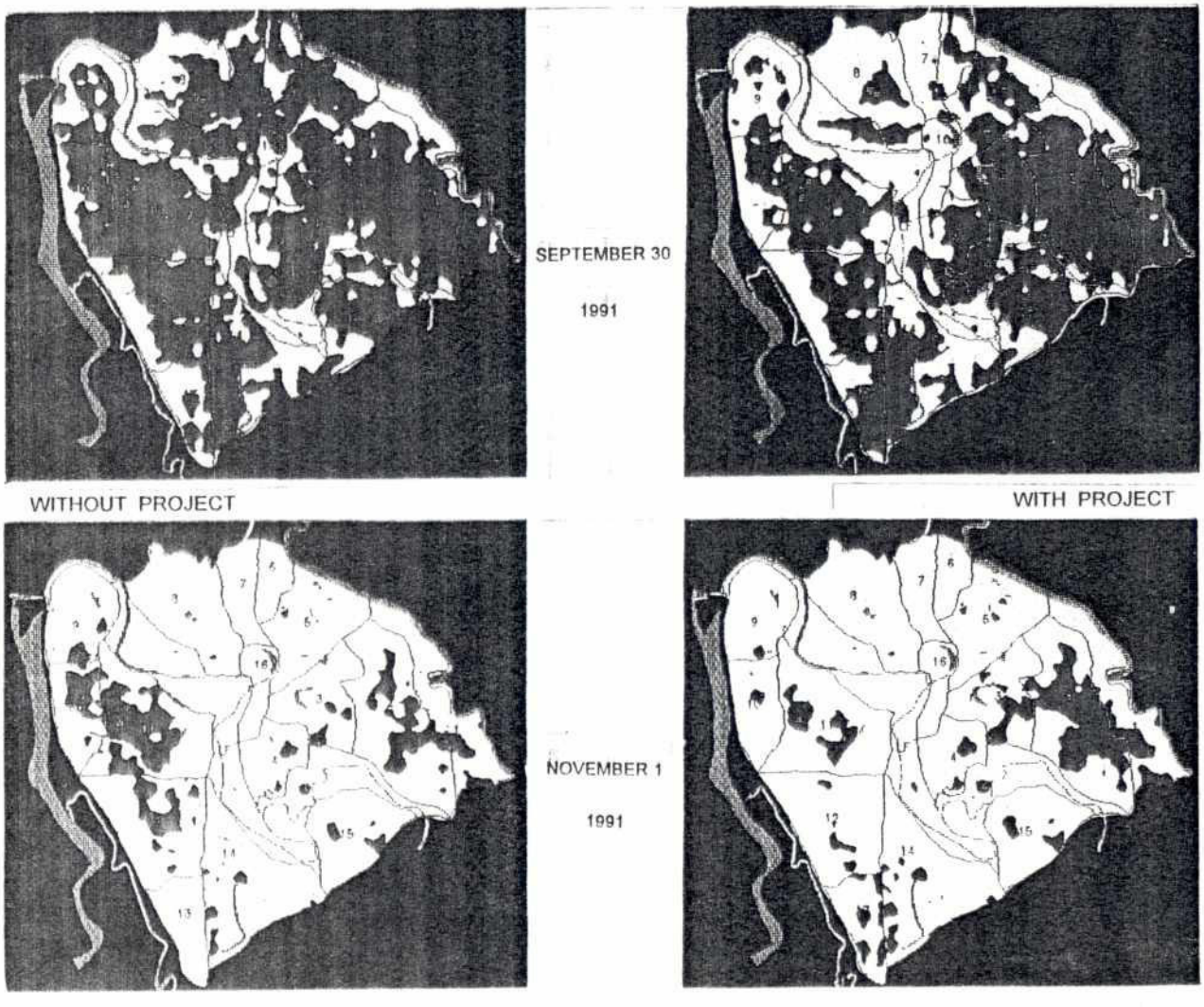

Figure 1 - Maps showing flood model results of Tangail compartment

Map information and statistics for compartment planning, socio-economic and environmental analyses were compiled in the *Tangail Area GIS Atlas* (FAP 19, 1992b). The GIS Atlas for the Tangail Area consists of 18 color thematic maps and 11 tables. In addition to serving as an index for GIS spatial data, the Atlas was used for planning GIS analyses and for disseminating results.

3.2.3 Charland Study

In this joint study by the Environmental Study (FAP 16) and FAP 19, a complete inventory of the people and resources of riverine *chars* was conducted for all the major rivers of Bangladesh covering a total area of 8,444 km^2 (almost 6% of Bangladesh).

"Char" is a Bengali term used usually for mid-channel islands that periodically emerge from the riverbed and includes attached sandbars along the riverbanks. The study included these chars as well as mainland areas unprotected by embankments.

About 1.8 million people live in the chars of the four major rivers (Jamuna, Ganges, Padma, and Meghna) out of a total of 4.3 million of the active floodplain population. The majority of them are concentrated along the Jamuna and Meghna.

Using the inventory data collected by this study and digital versions of historic maps and satellite images, the morphological development and distribution of charland was documented and analyzed using GIS. The GIS databases and the results of the analysis can be used for planning direct interventions for developing the char areas and for testing flood proofing measures and assessing their benefits.

GIS products in this study included a series of digital maps and satellite images showing the extent and resources of the chars of the Ganges, Padma, Jamuna and Meghna rivers (FAP 16/19, 1993a, 1993b, 1993c, 1993d). Charlands were classified based on their location, age and stability. Figure 2 shows the age of charlands of a part of the Jamuna River. From the inventory data, the migration patterns of the inhabitants of the charlands were shown, which, along with data on other human and physical resources, were related to one another and to river morphological data using GIS analyses.

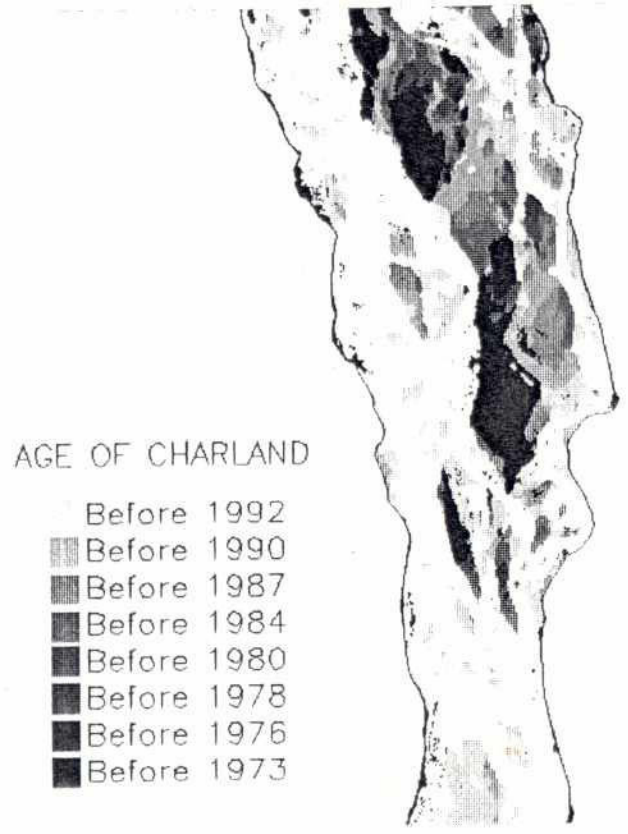

Figure 2 - Age of charlands of a part of the Jamuna River

3.2.4 River Morphology

This collaborative project with the Brahmaputra Right Embankment Strengthening Study (FAP 1) was undertaken to examine river morphology and channel dynamics for overall planning and designing of river training works. Using GIS and image processing, an extensive time series data set

was compiled from satellite images and historic maps dating back to the British survey of the 1760s. Time series and change-detection analysis using digital Landsat MSS and TM images was conducted for the period from 1973-92.

GIS was used to analyze the results to indicate trends in channel stability and migration of the Jamuna River. Analysis of these data yielded detailed tables, graphs, and maps which quantify and graphically portray bankline erosion and accretion, low-flow channel characteristics, and the evolution, movement, and lifetime of the numerous river chars. This information was used by FAP 1 to predict future bankline positions, assess and predict river bend behavior, describe relationships of bank erosion and island sediment storage, and identify stable chars that are suitable for infrastructure development and government extension efforts. The data and analysis also provided the basis for methods used in the Charland Study (FAP 16/19, 1993b), described above.

GIS maps were prepared illustrating river bankline movement due to erosion and accretion and other morphological changes. GIS analysis was used for study of channel and char dynamics to determine their effect on socio-economic conditions and migration pattern. From detailed data on the river planform, sediment mass balance tables indicative of the relationship between river banks and chars were also created. Figure 3 is an illustration showing channel migration from satellite images of the confluence of Padma and Meghna rivers which used analysis techniques similar to those used on the Jamuna River.

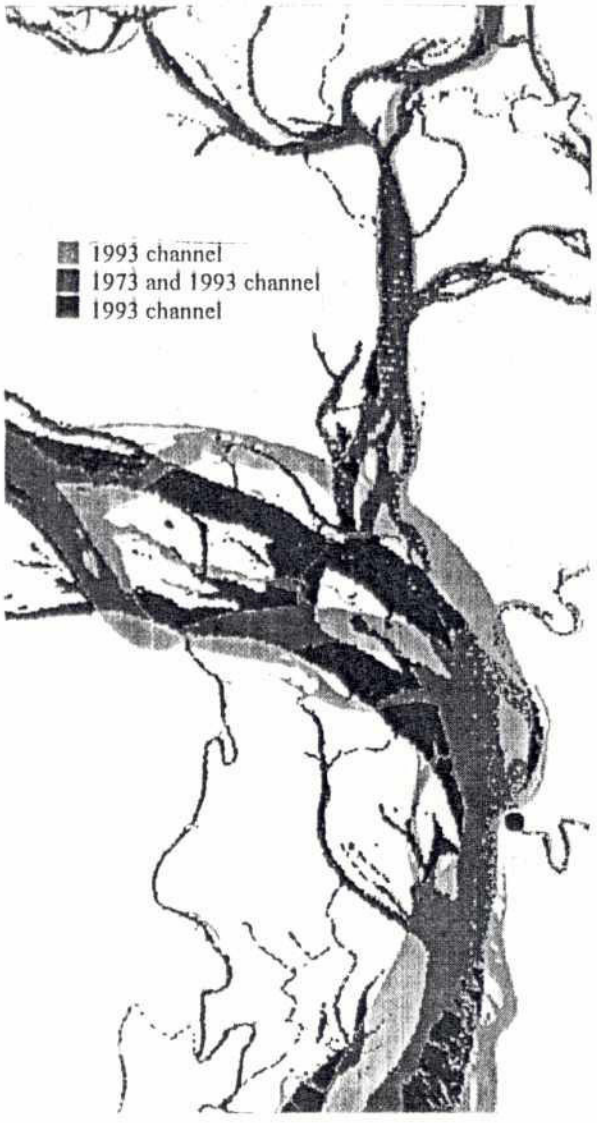

Figure 3 - Channel migration from satellite images of the confluence of Padma and Meghna rivers

3.2.5 A Study of Sedimentation in the Brahmaputra-Jamuna Floodplain

This was a joint project conducted by FAP 19 and FAP 16 to investigate the value of flood-borne sediments to agriculture on the floodplains of Bangladesh. The study focused on the left bank of the Jamuna river in an attempt to estimate the extent of sedimentation, determine the physical characteristics of the sediment, approximate the rates of deposition and assess the chemical characteristics and nutritive value of the sediments for agriculture.

GIS maps were developed for key parameters, including distance from sediment source, estimates

of flood depth, physiographic regions, spatial and temporal changes in the Jamuna river banklines, and sedimentation in an extreme flood (FAP 19/16, 1995).

IN addition, GIS was utilized in this study for mapping and analyzing natural resource and infrastructural conditions of the study area and sites.

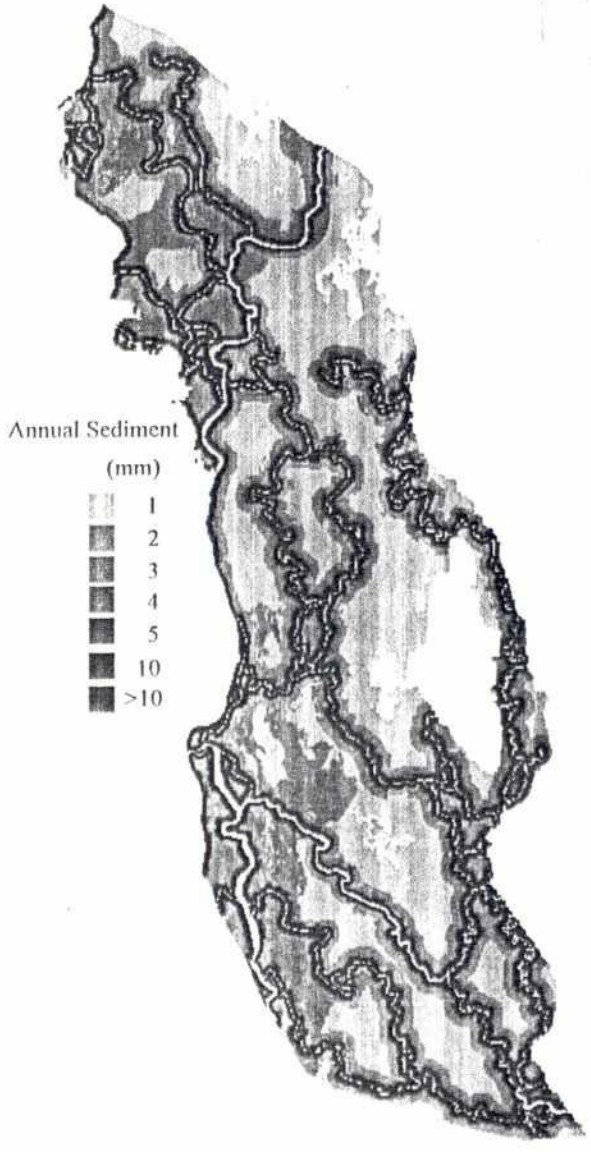

Figure 4 - GIS Sedimentation Model results

The digital database was used for baseline mapping, display and analysis of field data, and to construct a GIS model of floodplain sedimentation processes. The GIS model produced a regional map of sedimentation regimes, i.e., areas generally subjected to similar quantities of floodplain sediments as illustrated in Figure 4. A map of cumulative sediment deposition over the years 1954 - 1994 was also generated by the GIS model. This time span was chosen to match that of another aspect of the study which relied on analysis of the radioisotope ^{137}Cs in soil samples for determination of sediment accumulation rates.

3.2.6 Bhelumia-Bheduria Environmental Case Study

For the Bhelumia-Bheduria Study, GIS was used as a data platform for preparing base maps and for estimating flood inundation land type distribution using DEMs and information on the hydrology of the area (FAP 16/19, 1993a).

GIS was used to prepare a series of maps including a base map, administrative, infrastructure and hydrological units, and those showing the movement and changes in bankline and charlands of the Tetulia River. Also flood extent under different water levels, crop damage, and population density were documented. Figure 5 illustrates the Aus crop damage from floods of the study area.

3.3 Pilot Studies and Development of Technology Applications

3.3.1 Disaster Management Study

To assess the utility of GIS in anticipating and responding to the impact of storm surge flooding in the coastal area, a study was undertaken by FAP 19 with the support and assistance of the FPCO, the Disaster Coordination and Monitoring Unit (DCMU), CARE, Bangladesh and Development

Design Consultants (DDC). The study area included two thanas in the Chittagong District.

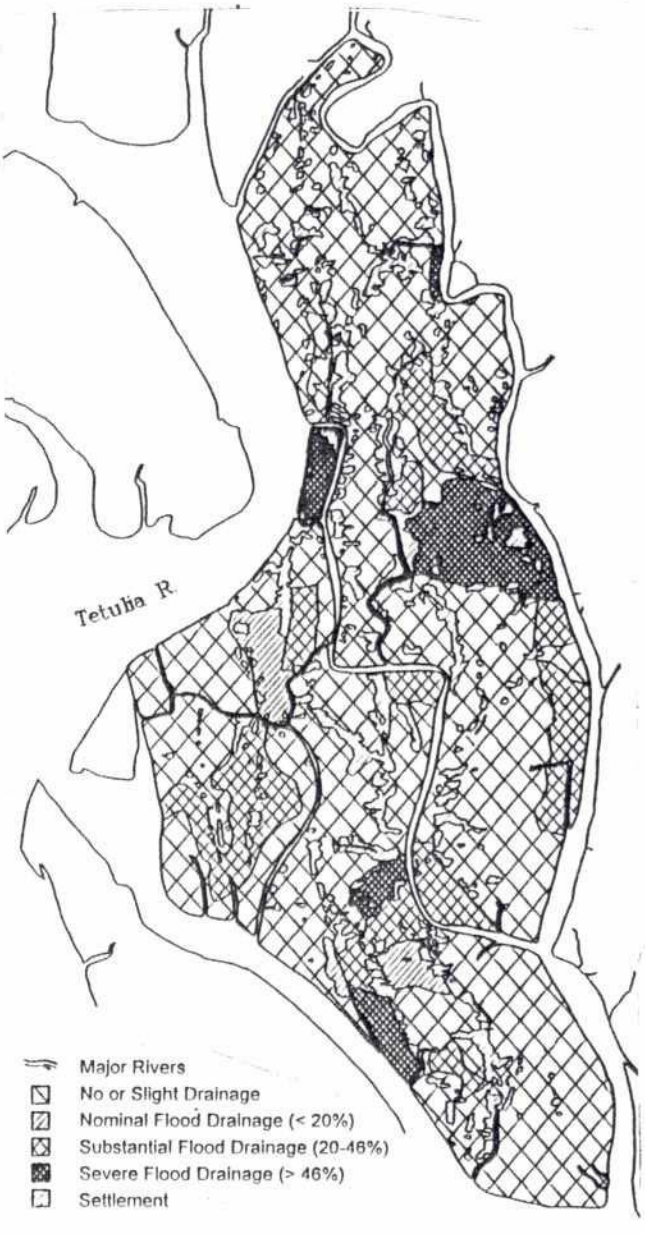

Figure 5 - Aus crop damage from floods

The digital databases and GIS analyses focused on storm surge modeling and impact assessment. Zones of flood depth were categorized according to risk. A series of vulnerability maps were developed for the population at risk. Shelter zoning was conducted by identifying catchment areas for cyclone shelters. The zoning was established by calculating the potential usage of existing shelters and the need to plan sites for new ones. Tables and maps were developed showing the cyclone shelters, their capacity and allocation of population (FAP 19, 1994a).

The findings from the study revealed that GIS is an important decision support tool, helping planners in site selection and in planning evacuation routes. Another benefit of using GIS in surge modeling is that a digital representation of a storm surge can immediately be combined with other spatial data in digital form to assess vulnerability or impact of a particular event. GIS could help the warning authorities by mapping an approaching storm, predicting a point of landfall, direction and windspeed, thus improving the tracking system. Since it is also possible to assess the area, people and property affected by GIS, relief needs can be estimated before or during a cyclone, leading to action plans to remedy any shortfall.

3.3.2 Satellite Based Radar for Flood Monitoring

Satellite-based radar remote sensing is a new technology offering high resolution imaging capability and an opportunity to "see" through cloud cover and acquire data during the rainy season both day and night. Through the operational advantage and potential applications in tropical environments like Bangladesh, it can provide valuable information for identifying flooded areas, coastal and marine features and land use characteristics.

This study, the first to explore satellite-based radar in Bangladesh, mapped the extent of flooding during the monsoon and identified the non-flooded settlements, homestead forests and certain crops by using SAR data. Figure 6 shows the flooded and

non-flooded areas in the northwestern region of Bangladesh as classified by the Radar Study.

The findings of the study revealed that SAR application potentials exist in situations where optical remote sensing is impossible or severely restricted because of environmental conditions FAP 19, 1995f). Digital files and prints were developed of geocorrected and processed radar satellite images. Flood extent maps of two areas, Sirajganj and Sylhet, were prepared and compared with ground data from an extensive collection program. Image results compared favorably with ground data with about 80 percent agreement. The potential of this technology for flood monitoring was clearly demonstrated in this project. The operational use of satellite-based radar is believed to have an enormous potential for monitoring floods and other environmental conditions in Bangladesh. The technology will be especially useful when used in conjunction with other information from terrain and flood models.

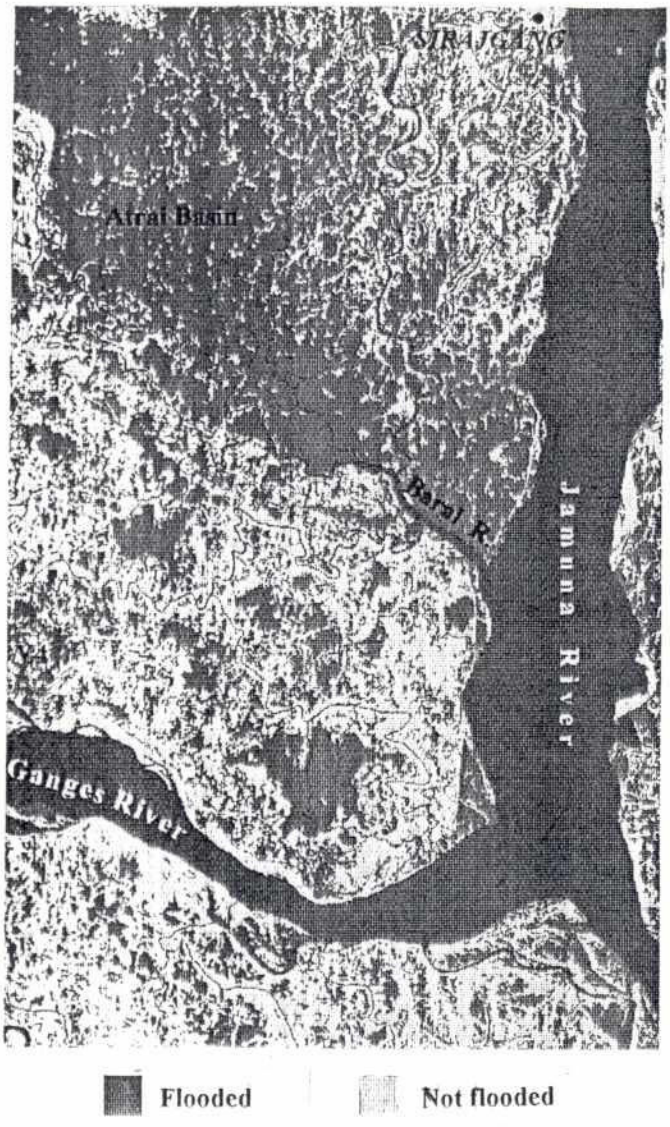

Figure 6 - Radar image classification of a part of Atrai Basin

3.3.3 Applications for IFFD Project

This prototype project was undertaken to determine the potential of GIS for infrastructure development, planning and monitoring of the Integrated Food For Development Project implemented by LGED and CARE, Bangladesh. This collaborative GIS prototype project was initiated and completed for Manikganj Thana. As a part of the study, an analysis of impacts of roads on the environment was attempted . It also checked availability and quality of spatial and attribute databases currently used by the IFFD project.

IFFD's methods of selecting roads for improvement and for considering environmental factors were examined. Existing digital data used by IFFD and FAP 19's digital data were evaluated for linking spatial and attribute road inventory data. The road network with structures from LGED's databases, and the flood inundation landtype map, from FAP 19 databases, are illustrated in Figure 7. Methods of delineating road catchment boundaries and calculation of road catchment population were

explored. In addition, global positioning system (GPS) survey was used to test its effectiveness in road inventory and mapping (FAP 19, 1995d).

Based on the applications demonstrated, FAP 19 has made recommendations to the IFFD project regarding future GIS resources required to fully assist planners in the project.

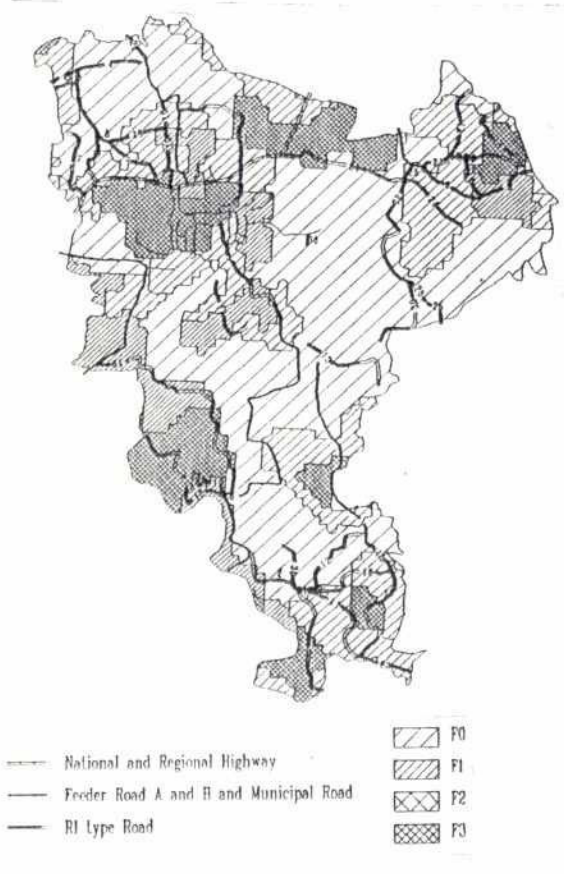

Figure 7 - Road network through different landtypes

3.3.4 Flood Forecasting and Warning

In this demonstration, BWDB flood forecasting reports were digitally reconstructed and analyzed. Results were presented as maps, which are more easily interpreted than the complex tables currently in use. If taken up operationally, this presentation and analyses could better enable planners and managers to assess daily flood scenarios and provide information for improved water management. Water level data of 38 gauging stations were used for the study.

The output of this study was a series of GIS maps generated for the three-day period 23-26 July, 1993 indicating the specific trends in water level occurring in the major rivers (FAP 19, 1994b). In visual form the flood conditions and trends are easily interpreted. Schematics of flood warning and river rise/fall for specific dates are shown in Figure 8.

3.4 Database Development

Over the past four years FAP 19 developed and archived large quantities of data into a user-oriented format. These data are described in brief in the following sections. (For more detail see Appendix D.)

3.4.1 National Database for Land and Water Resources Planning

The National Database Project was undertaken to provide a GIS capability to assist in planning and managing geographic information for the Flood Action Plan (FAP), and to promote standardized data protocols and formats for providing unrestricted access to water resources managers, planners and other legitimate users. The national level data is useful at regional and sub-regional levels for display and mapping, as well as for spatial analysis.

The project output consists of spatial data compiled and digitized as part of FAP 19 GIS application projects. Also, existing data was collected from external sources, reformatted, edited, and updated to provide an integrated GIS with a consistent data protocol (FAP 19, 1993g, 1995c).

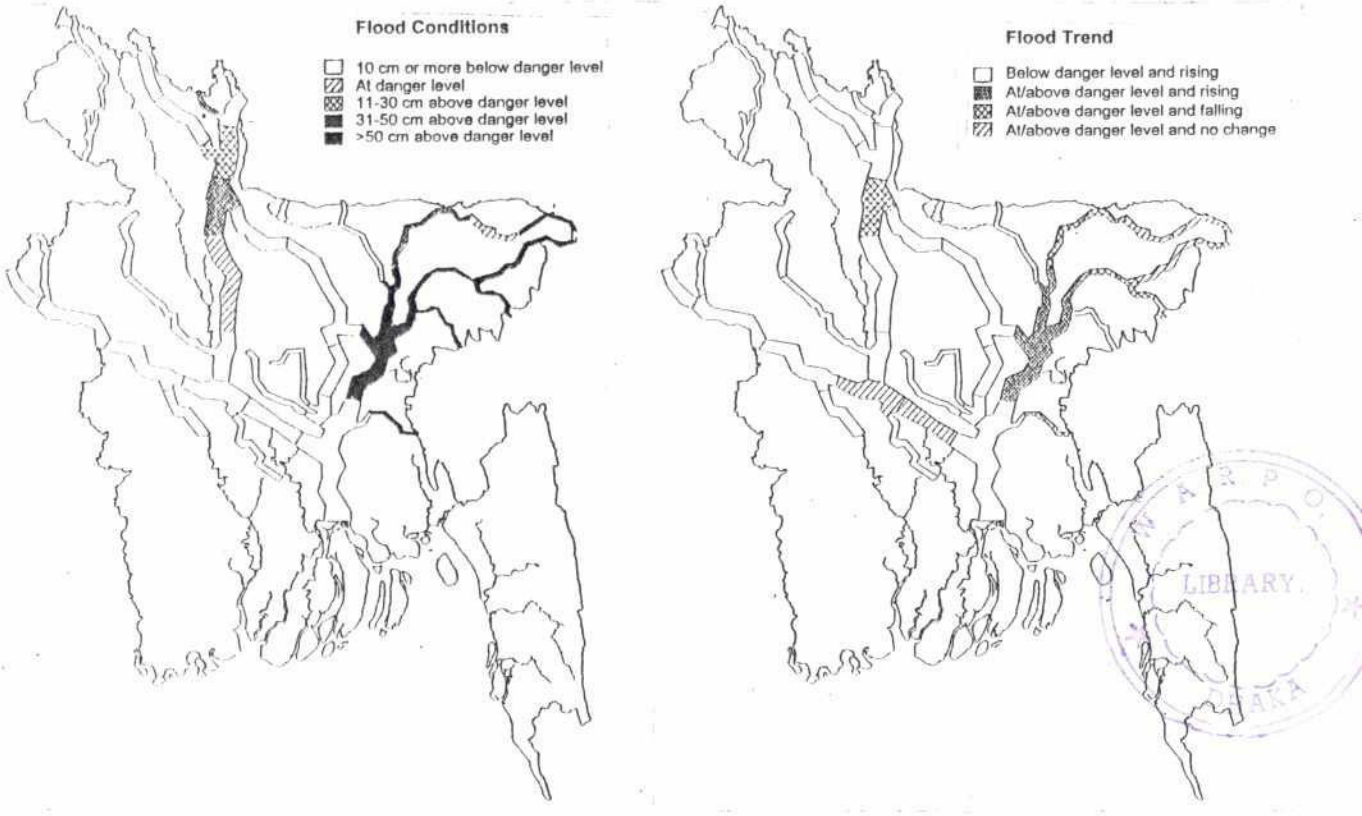

Figure 8 - Schematics of flood warning (left) of 23July 1993 1nd river rise/fall (right) of 25 July 1993

Various data themes at national, district and thana levels were prepared. Linkage with the 1991 census data was made to enable display and manipulation of these data at a national level. The different themes are shown in Table 1 above. The hydrology theme is illustrated for a part of the Sundarban area in Figure 9 and flood inundation land type map for a part of the northwestern region is shown in Figure 10.

Many of the hardcopy displays of the various thematic layers are compiled in the National Database Atlas. The A-3 size atlas contains 15 color maps, 11 in vector format and 4 in raster format.

The FAP 19 databases are being used for a variety of purposes. The various data themes can be combined to form new layers of spatial information. An example of one such derived theme, the flood inundation land type, is a result of GIS analysis using the soil association database and the DEM digital data. Flood depth maps have a variety of useful applications, especially in the design of flood control structures such as embankments, and as input data for agronomic and environmental studies. The FAP 19 databases have been used by other projects and organizations. They have been used by the regional FAP studies, such as FAP 4, FAP 25, FAP 24, FAP 20 and FAP 21/22 for hydrological and hydrodynamic modeling, river training studies, for compartment design and management, and for water resources planning and management.

Table 2 Summary of the FAP 19 National Database

Data Theme	Geographic Features	Attribute Data	Source Map/Scale
Administrative Boundaries	Thana, District, National	BBS Census Data	AEZ Maps; 1:250,000
Infrastructure	Roads, Railways	—	AEZ Maps; 1:250,000
Hydrography	Rivers, *Khals, Beels, Chars*	River Width	SPOT Image Maps; 1:50,000
Soils	AEZ Soil Association	AEZ Soil Attributes	AEZ Maps; 1:250,000
Topography	DEM	Elevation (0.1 m units)	BWDB Maps; 1:7920, 1:15840
Hydrometric Stations	Locations of Water Level, Discharge, Rainfall Stations	Monitoring Devices, etc.	BWDB Maps; 1:750,000
Demography	[Thana Level Attributes]	Population, Households, etc.	[AEZ Maps; 1:250,000]
Flood Inundation Land Type	Normal Flood Depth	F_0 - F_4	AEZ, BWDB, FAP 19
Agroclimatic Data	Reference Moisture Zones, Thermal Zones	Growing Period, Temperature	AEZ Maps; 1:750,000
Regional/Local Data Sets	Various	Groundwater, Census, Environmental, Socioeconomic	Various

Apart from FAP studies, the databases were used for climate change studies by the Bangladesh Agricultural Research Council (BARC), and other research organizations. The display and analysis of national level census data is useful for research and planning for the national statistical agency as well as for university research work.

3.4.2 Digital Elevation Model

During the first phase, FAP 19 produced a Digital Elevation Model (DEM) for Bangladesh with a one kilometer ground resolution using MPO data. This DEM was not suitable for many regional analyses and planning exercises and hence, FAP 19 initiated a project to produce a medium-resolution (500 m x 500 m) DEM based on generalized BWDB spot elevation points (FAP 19, 1995b).

The main objective of this project was to construct a semi-detailed regional- and national-level DEM with horizontal resolution for use in automated terrain analysis and a 3-dimensional terrain visualization (Figure 11) as required by water resource, environment, and engineering GIS applications.

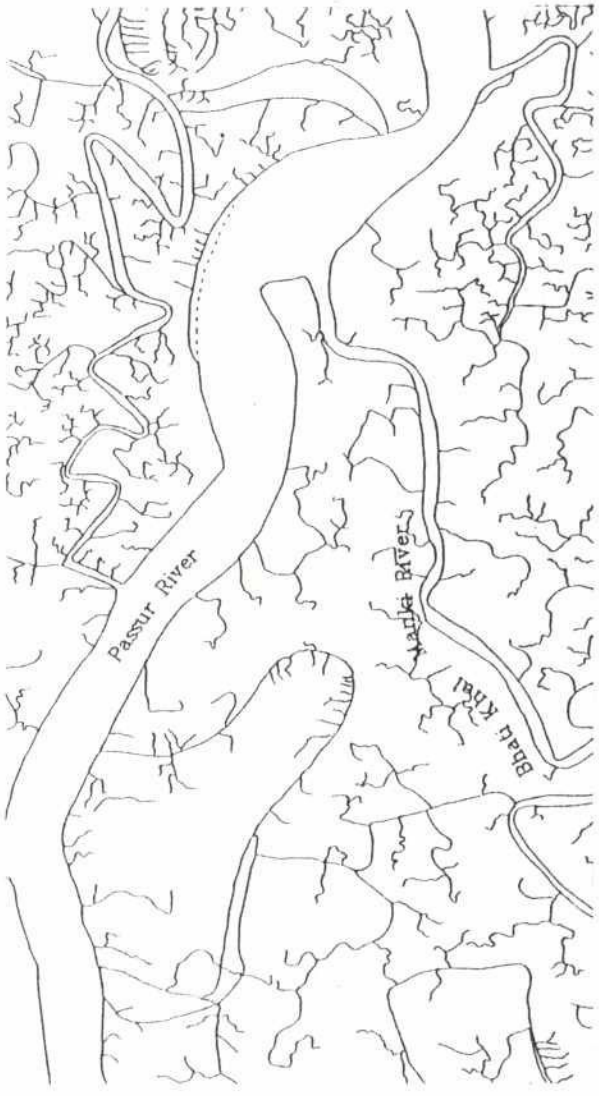

Figure 9 - Hydrology of a part of the Sundarban area

Six primary DEM products were generated by this project; four with regional coverage and two with nationwide coverage. The files have a 300 m pixel size and a 0.1 m elevation interval. Fig. 9 shows the National DEM constructed from the 500m. This medium resolution DEM of Bangladesh is a substantially improved one than the previously constructed low resolution of 1 km for use in national and regional water resources management within the Flood Action Plan including flood modeling and mapping, flood forecasting and floodplain sedimentation modeling.

GIS and DEMs are also useful for environmental applications such as soil erosion modeling, watershed analysis, landscape visibility analysis, landscape modeling, and geomorphological studies. In addition, these technologies can help engineers plan the construction of flood control structures, irrigation canals, dams, roads, and utility networks.

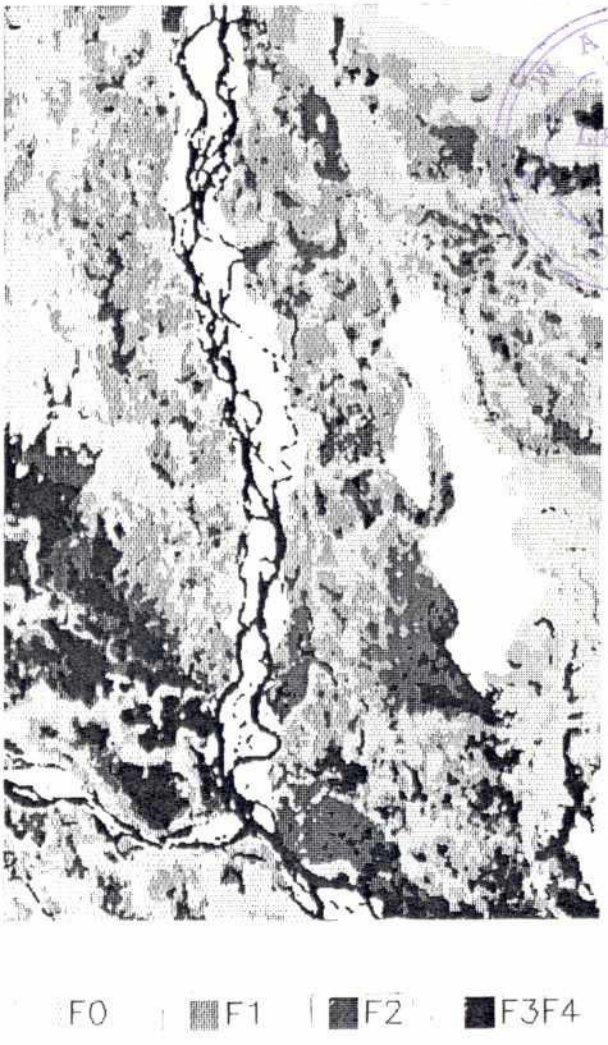

Figure 10 - Flood Inundation Land Type of a part of northwestern region of Bangladesh

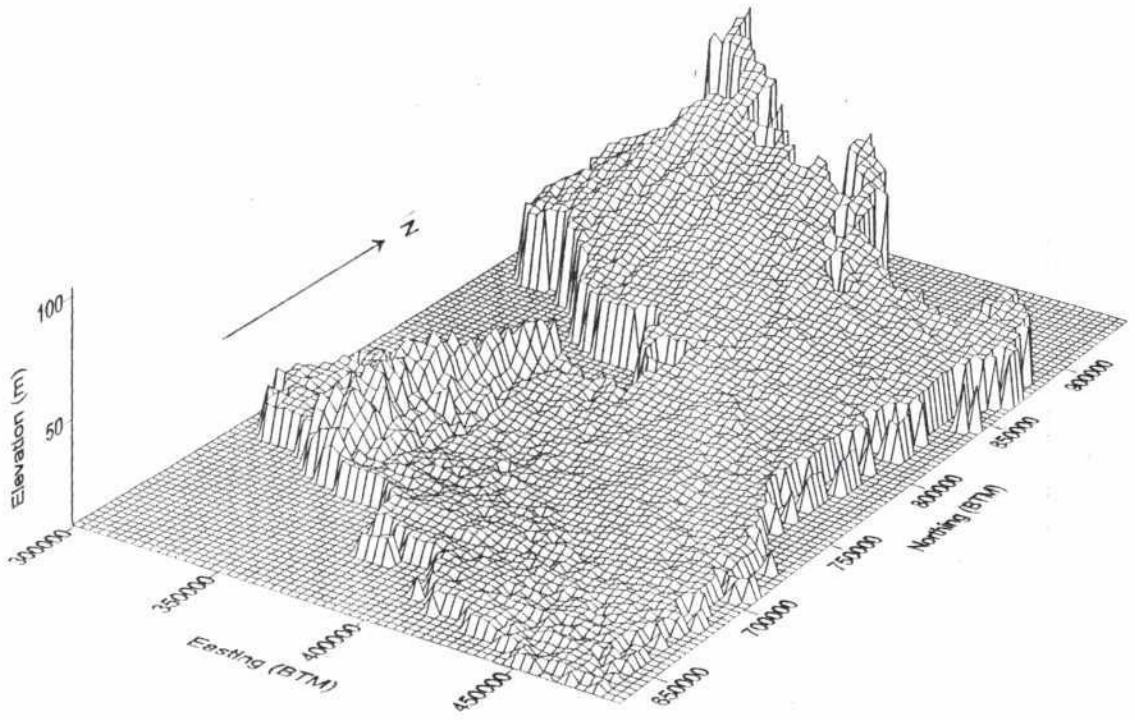

Figure 11 - Wire frame 3-D model of northwestern Bangladesh generated from a DEM

3.5 Towards Sustainability of GIS Technology

FAP 19 has built and developed GIS technology in Bangladesh through a sustained effort of training and transferring technology. This has been accomplished through a variety of means such as the GIS Users Group, collaboration studies, both on-the-job and structured professionals training and through advice and support of other organizations interested in developing GIS capability.

3.5.1 Needs Assessment and GIS Survey

An analysis of existing GIS resources in Bangladesh was considered important to the efficient design and planning of FAP 19 activities. To provide a basis for the assessment, a survey of GIS resources was conducted during the initial stages in April-May 1991. The existing and planned GIS resources were identified in a report which described associated computer technology, GIS inputs such as digital spatial data, maps and tabular databases, GIS analysis and modeling functions, trained personnel and training facilities. To keep current with GIS developments in Bangladesh, the initial report *GIS*

Resources in Bangladesh (1991a), has been annually updated by FAP 19.

3.5.2 Initiated and Supported GIS Users Group

Initial FAP 19 queries revealed an interest in organizing a GIS users group in Bangladesh. Under FAP 19 initiative and leadership, such a group was formed in August, 1991. Later, an executive committee was formed and a membership registration system with a nominal annual fee was introduced.

The "GIS Users Group, Bangladesh", as it is called, acts as a forum for exchange of ideas, exposure to technical issues, and presentations by professionals and vendors. The site for the meetings has rotated among various organizations. Within a span of four years, ten meetings have been held and the membership role now stands at around one hundred.

3.5.3 Established GIS Standards and Protocols

The format and quality of a GIS database determine its utility for the developer and for use by other GISs. FAP 19 initiated numerous discussions and meetings with GIS users to determine data needs and formats. Two working groups were formed: a Database Working Group, to discuss issues on data protocols and standardization of data formats, and a GPS Users Working Group, to learn about the various types and uses of GPS in Bangladesh.

The GIS software used by FAP 19 are also widely used internationally. The GIS databases are stored in common formats. Also extensive utilities are provided with the software so that interchange with other commonly used formats can take place.

Guidelines for data exchange of ARC/INFO coverages have been prepared as part of the FAP 19 National Database Project. Broad guidelines for data documentation and quality standards also have been included as a part of the numerous technical notes, reports and a data archive document prepared by FAP 19 (refer to Appendix E). These documents ensure the dissemination of GIS standards and protocols.

One important step toward standardization is the use of a single mapping projection for digital mapping in the country. FAP 19 adapted and promoted a system and named it as the *Bangladesh Transverse Mercator Projection* (FAP 19, 1992a). This map projection is being used by other GISs, which facilitates exchange of digital information.

3.5.4 National Databank

One of the objectives of FAP 19 was to promote unrestricted access to water resources management and planning information for legitimate users. FAP 19 has provided technical information and assistance not only to FAPs but also to other organizations in Bangladesh and abroad. (See Appendices F and G).

The GIS database developed over the past four years has been incorporated into a cooperative databank, called the FPCO/FAP 19 Cooperative GIS Databank, for access and use of registered users. Users are required to provide updates of the cooperative data back to FPCO/FAP 19 and the cooperative agreement will allow access to other databases of Bangladesh developed by the user. The data is provided in diskettes and CD-ROMs along with supporting reports, archives and documentation. (See Appendix H.)

3.5.5 Established GIS Training Center

One of the accomplishments of FAP 19 was the establishment of the GIS Training Center. The Center conducted numerous training courses in GIS and related technologies for GOB officials, nongovernment organizations, private agencies, and

consultants. Details of the training are provided in Section 3.6 below.

3.5.6 Institutionalization

FAP 19 has become a recognized "center of excellence" in the use of GIS and related information technologies in Bangladesh. In order to sustain this capability beyond the life of the project, a strategy was developed for continued training and institutionalization.

Institutionalization issues were addressed in several documents as a series: FAP 19 Institutional Issues (1992, 1993), Background Paper on Locating FAP 19's GIS (May 1994), Preliminary Recommendations for Institutionalization (1994), Proposed GIS Technology Transfer program (1994), a paper on Proposed Collaborative Database in Bangladesh (1995), and the Project Document developed by the Dutch government and GOB for the Environment and GIS Support Project for Water Sector Planning.

3.6 Training

Since its inception FAP 19 provided on-the-job training to its staff and training for others, both from the public and private sector, in structured courses.

The total number of trainees stands at 169 for the various courses and includes intensive training to over 50 individuals. The courses include Introductory GIS, pcARC/INFO, ERDAS, Raster GIS and Image Processing, pcTIN, Training of Trainers, Radar Remote Sensing and an EIA-GIS Study Tour. (For details refer to Appendix I).

3.6.1 Accreditation of Training Center and Certification

One of the major achievements of FAP 19 and ISPAN has been the accreditation of FAP 19's GIS Training Center as an ARC/INFO Learning Center. The accreditation was given by the Environmental Systems Research Institute (ESRI) of California, the developer of the ARC/INFO GIS system. This is the first certified center in Bangladesh for teaching this sophisticated geographic information system software.

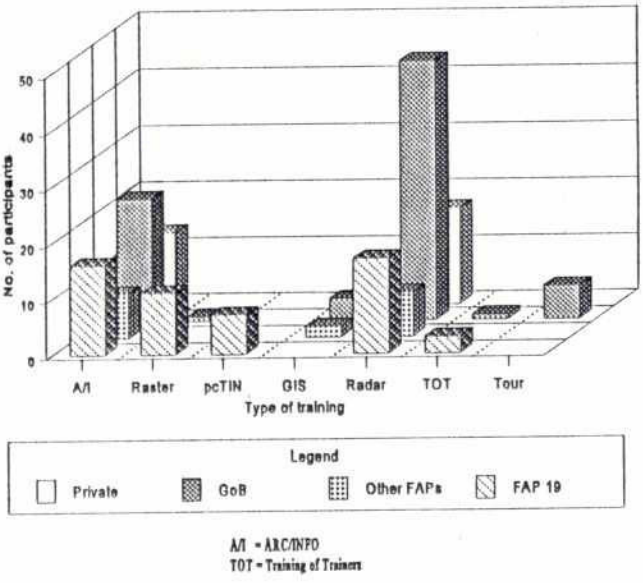

Figure 12 - GIS Training under FAP 19

Together with the accreditation of the training center, ESRI also certified four of FAP 19's professional staff as ARC/INFO trainers after an intensive training of trainers and certification process. These certified trainers have now conducted four training sessions on pcARC/INFO for 31 participants from government organizations, other FAP studies, autonomous bodies, development programs, NGOs and private agencies.

3.6.2 Structured Training Program

The training program under FAP 19 included seven courses on pcARC/INFO, one each on ERDAS, Raster GIS & Image Processing, pcTIN, Training of Trainers, and Radar Remote Sensing. FAP 19 also sponsored the GIS Introductory Course at ICIMOD, Nepal and the EIA-GIS Study Tour to the USA.

FAP 19 developed an intensive ten-day training program on pcARC/INFO using Environmental Systems Research Institute (ESRI) training materials and FAP 19 databases for project work and case studies. In addition to theoretical background and GIS principles, it provides hands-on training exercises to the participants.

Apart from its own staff, FAP 19 has provided training to both private sector and individuals from several government agencies including FPCO and others from water and other sectors. A special two-day training workshop on radar remote sensing was conducted by two expatriate radar experts for about a hundred participants. In addition, an EIA-GIS study tour of the U.S. was also conducted for six senior GOB officials. (For details see Appendix I.)

3.6.3 On-the-Job Training

FAP 19 provided extensive on-the-job training to seventeen of its staff during its four-year period of existence. A Training of GIS Trainers course was also conducted by an expatriate consultant for selected staff of FAP 19 which resulted in their certification as GIS trainers and reduced the need for expatriate experts. In support of this training, extensive data sets, exercises and materials were developed including manuals on Introduction to GIS and Remote Sensing in Environmental Impact Assessment for use in the GIS component of the FAP 16 EIA training workshops.

3.7 Assistance to FAPs and Other Projects

Because of its proven GIS and image processing resources and capabilities, FAP 19's support was requested by a wide range of organizations, including other FAP studies, GOB organizations, NGOs, and research institutions. For this purpose, several special and pilot studies were conducted, particularly for water resources applications, and a variety of digital spatial data were provided for use in research and for development projects. For example, at the request of a World Bank project team, spatial analysis using FAP 19's data on flood inundation landtype was used for assessing the fisheries impact of the closure of the Old Dhaleswari River intake by the Jamuna Bridge project. In another example, shown in Figure 12, GIS surfacing techniques were used for creating bathymetric relief maps for a portion of the Jamuna River using data of the River Survey Project (FAP 24). A summary of the assistance provided by FAP 19 to other FAP projects is provided in Appendix F, and to other organizations in Appendix G.

4. OUTPUTS

By using GIS and related technologies in the various application and pilot studies, FAP 19 developed new data processing techniques, performed spatial analyses, created a number of databases and produced a variety of information products for planning and environmental monitoring in Bangladesh.

The FAP 19 output consists of the following:

- Digital databases;
- Technical notes, reports, and a data archive;
- Maps, images and graphics for various projects;
- Trained GIS personnel.

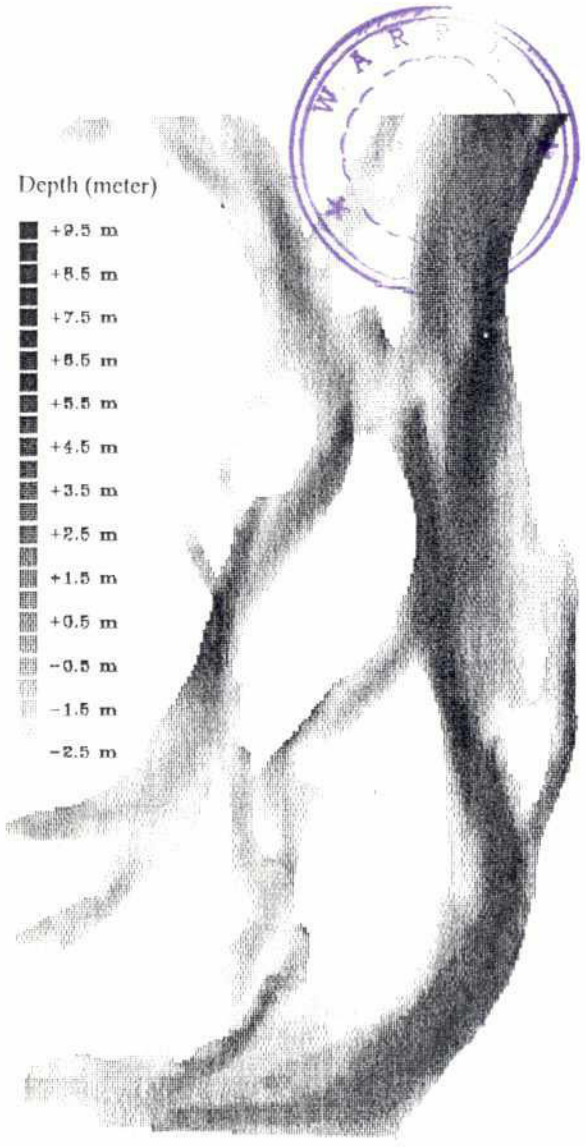

Figure 13 - Bathymetric map of a part of the Jamuna River

4.1 Digital Databases

FAP 19 developed an extensive digital database consisting of vector and raster GIS files, attribute files and digital satellite images. The projects which developed these data are described in Sections 3.2 - 3.4, above. The data are fully documented in the series of reports produced by FAP 19 (Appendix E) and in the archive documents. Listing of databases is provided in Appendix D.

4.2 Reports, Technical Notes, and Data Archive

For preserving the work of FAP 19's various projects - including the methodologies involved, the data used and the results achieved - FAP 19 documented the procedures and archived the data in technical notes, reports and archive documents. The data are backed up in digital format on diskettes, magnetic tapes and CDS. Among the written documentation produced by FAP 19 are 9 technical notes, 19 reports, and a three-volume archive document (see Appendix E).

4.3 Maps, Images and Graphics

A variety of maps, images and graphics were prepared for the numerous projects of FAP 19. Many of these graphics are available in FAP 19's reports and in posters and other presentations. Most of these graphics are available with FAP 19 in their original format, digital and/or hardcopy, and could be reproduced if needed. In addition, FAP 19 maintains a library of satellite images and maps, in a variety of formats and sizes.

4.4 Trained GIS personnel

Although some of the original FAP 19 project staff have left for advanced degrees overseas, the remaining twelve continue to be a major asset for GIS-based planning and development. All have a sound knowledge of mapping, databases, and GIS, but their value as a team must be recognized due to their individual and complementary specializations, including vector GIS, database construction, GIS modeling, and image processing.

Other people trained at various times by FAP 19 served as GIS professionals and provided GIS leadership in their institutions. Such institutions are FAP 2, FAP 4, FAP 20, FAP 25, SWMC, SPARRSO, NMIDP, and LGED.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Value of GIS Technology

The FAP 19 project has established the effective tools of GIS and related technologies for water resources planning and management in Bangladesh. From a broader perspective, FAP 19 has proven that if properly designed and implemented, GIS can be a powerful medium for sustainable development in Bangladesh. It can serve multiple sectors simultaneously and can function as an intermediary among interests and institutions. And, because maps and images can be understood even by those without formal education, the use of maps can encourage and enable local people to participate in the planning process. The tools developed by FAP 19 have already proven their value in the water resources sector of Bangladesh. They deserve to be nurtured and expanded to realize their full potential in present and future planning efforts.

In addition to developing GIS databases and applications, FAP 19 has explored new, related technologies and explored applications in new areas. Areas which are particularly promising, and which are recommended for further development, are satellite-based radar for flood monitoring, and use of GIS in disaster management.

5.2 Awareness

Since the initiation of the FAP 19 project there has been a great increase in awareness of GIS and related technologies by development interests in Bangladesh. This is due, in part, to the efforts of FAP 19 to develop the technology and to promote coordination among actual and potential GIS users. These efforts began in 1991 with FAP 19's establishment of the Bangladesh GIS User's Group and included participation and presentations in other workshops, training programs, conferences and seminars sponsored by the FAP and other organizations. Although they are not strictly quantifiable, the benefits of these awareness-building efforts are significant, and they should be encouraged in future programs.

5.3 FAP 19 Staff

The core professional staff (about 18 persons over the life of the project) have been the real key to FAP 19's success and one of the major assets that the project is leaving behind. Some staff have left for more secure employment in related fields and some have moved on to graduate studies in the USA and Europe, specializing in a field where their GIS skills are useful: urban planning, geomorphology, etc. Many have remained with the project and are interested to continue with the technology through follow-on projects in the water sector. Since these individuals have skills and training which required years to develop, their continuation with the technology in water, land and environmental resources is strongly recommended.

5.4 GIS Training

GIS training has been one of the most successful aspects of the FAP 19 project. Aside from one and two-day workshops, FAP 19 provided training to some 50 to 60 individuals in GIS and/or image processing. Most private sector GIS professionals in Bangladesh—those operating and applying GIS as an integral part of their work—received their GIS training from FAP 19 as did many of those in government agencies. Prior to 1995, almost all of the GIS training in Bangladesh, including that of the FAP 19 project, was conducted by expatriates. To develop training capability in Bangladesh, in 1994 FAP 19 selected four of its staff, all with three years or more of intensive experience using GIS, for a training of trainers program. An expatriate worked with these four, developing not only their technical skills but their training skills as well. The four went through a rigorous procedure with Environmental Systems Research Institute (ESRI), the U.S. based developer of the world's most widely used software,

ARC/INFO. The result was that all four were accredited as GIS trainers; they are the only persons in Bangladesh with this certification and they are allowed to teach GIS courses using ARC/INFO software anywhere in the world.

With accredited GIS instructors, and with the GIS training facilities in the ISPAN office, FAP 19 then applied with ESRI to be certified as an ARC/INFO Learning Center (ALC). The certification was granted—the first of its kind in Bangladesh—and ESRI provided and authorized use of their extensive training materials and provided six licenses for use in the training center. An intensive, and very professional GIS training program was developed based on the ESRI materials and supplemented with case studies and exercises using data, maps and problems of Bangladesh. Although the ESRI certification was granted to the FAP 19 project, it is possible to sustain the ALC if the certified trainers are utilized and if the hardware, software and other training facilities of FAP 19 remain accessible. A GIS training facility of international standard is, for the first time, available in Bangladesh with instruction provided by certified Bangladeshis in either Bengali or the English language. Every effort should be made to keep this valuable asset active and to take advantage of its services.

5.5 Access to Maps and Data

With respect to access to data in general, and to maps in particular, the traditional practices in various government agencies have undergone a perceptible change in recent times. They are opening up and it seems that computer technology can be a real catalyst in this process. FPCO has played a positive role in these developments.

The restriction of maps is a holdover from earlier days when government security was a factor. There is now little rationale for map restriction, given that most of the maps are outdated and given that high resolution satellite images of the entire country can be purchased, at relatively low cost, from many sources including those in the USA, Canada, France, Thailand and India.

FAP 19 has been involved in inter-sectoral meetings regarding use of GIS, avoidance of duplication and sharing of data and resources. FAP 19 has consistently fostered cooperation among institutions and projects and encouraged the sharing of knowledge and digital data.

In an effort to institutionalize the FAP 19 capability, a data sharing policy has been established with the setting up of the "FPCO/FAP 19 Cooperative Databank". FPCO has endorsed this program, which provides a substantial dataset developed by the FAP 19 project at essentially no cost. The response to this program, which was only finalized in early June 1995, has been very enthusiastic. Applications have been received from government agencies, NGOs and projects in Bangladesh, as well as universities from the region and several other continents. It is believed that cooperative efforts in constructing spatial databases are in the best interest of Bangladesh. There is now a good opportunity for mutual efforts, especially since digital databases are just beginning to be developed.

5.6 Commitment Needed for Successful GIS

The overriding appeal of GIS technology is its ability to present information and to analyze it in meaningful ways often not possible using conventional approaches. However, the complexities and limitations of the technology and the expertise required for making full use of it are commonly not understood and all too often not even recognized. This can result in either false expectations of the technology, or the placement of GISs in environments where the skills for its proper use do not develop. The design of successful and sustainable GIS installations can best address these issues by including comprehensive programs which contain the requisite hardware, software, and facility resources as well as the means for identifying and

selecting qualified personnel to create and maintain the GIS capability.

5.7 GIS Capability in the Government

The Bangladesh Government has recognized the need to train those from the water resources sector in GIS and related technologies. FAP 19 provided training courses, which exposed the trainees and provided skills for developing GIS expertise. However, it is only through use of the skills that one actually develops the expertise; this is best accomplished through months or years of experience with application projects.

The best opportunity to develop this capability would be through a follow-on project which builds on the experience of FAP 19. To fully develop GIS within the Water Resources Ministry, capable and motivated government service professionals, interested in taking up the technology as a substantial part of their career, must be selected for training and assigned to work with the intensive GIS project. This approach should be formulated early in the project and should involve those targeted as GIS analysts as well as those targeted for eventual management positions.

5.8 The Way Forward

FAP 19's GIS facility includes a fully functioning system of hardware and software, maps and digital data, and a highly trained and integrated professional staff. The range of databases, pilot studies and full application projects completed by FAP 19 is quite substantial by any standard. The GIS capability developed under FAP 19 is vital to improved national water sector planning. If this capability is not institutionalized as a part of a permanent water sector planning agency, many of these planning tools will be lost. The best possible solution for retaining this capability, and building on the existing knowledge, would be a follow-on project geared toward developing and supporting a permanent national-level water resources planning organization, likely to be formed from a merger of WARPO and FPCO. Such a project should lead to the formation of an operational GIS and image processing facility and a national water resources information and planning system.

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FAP 19, 1995a. *A Semi-Detailed River Database for Bangladesh.* Dhaka: Flood Plan Coordination Organization, Ministry of Water Resources. (Prepared by Irrigation Support Project for Asia and the Near East).

FAP 19, 1995b. *Bangladesh National Digital Elevation Model.* Dhaka: Flood Plan Coordination Organization, Ministry of Water Resources. (Prepared by Irrigation Support Project for Asia and the Near East).

FAP 19, 1995c. *Bangladesh National Level GIS Database.* Dhaka: Flood Plan Coordination Organization, Ministry Water Resources. (Prepared by Irrigation Support Project for Asia and the Near East).

FAP 19, 1995d. *GIS Potential for IFFD: A Case Study of Manikganj.* Dhaka: Flood Plan Coordination Organization, Ministry of Water Resources. (Prepared by Irrigation Support Project for Asia and the Near East).

FAP 19, 1995e. *Satellite-Based Radar for Flood Monitoring in Bangladesh.* Dhaka: Flood Plan Coordination Organization, Ministry of Water Resources. (Prepared by Irrigation Support Project for Asia and the Near East).

FAP 19/16, 1995. *A Study of Sedimentation in the Brahmaputra-Jamuna Floodplain.* Dhaka: Flood Plan Coordination Organization, Ministry of Water Resources. (Prepared by Irrigation Support Project for Asia and the Near East).

Appendices

Appendix A

Table 1 - Staff Designation of Local Professionals from April 91-June 95

	Name	Designation
1	Abdul Malik Faruq	GIS Graphics Analyst
2	Abdul Matin Miazi	GIS Specialist
3	Ahmadul Hassan	GIS Technical Manager
4	Aneeqa Shireen Syed	GIS Analyst
5	Dr. Anwar Hossain	GIS Consultant
7	Chapal Chowdhury	GIS Specialist
8	Dr. Dilip Barua	Sedimentologist
9	Golam M. Kamal	Case Study Co-ordinator
10	Iffat Huque	GIS Specialist
11	Dr. I.G. Chowdhury	GIS Mgr/Trng Specialist
12	Md. Faruque	Jr. Soil Scientist
17	Md. Hassan Ali	GIS Specialist
18	Md. Jakariya	Jr. Social Scientist
19	Md. Mominul Huq	Computer Co-ordinator
20	Md. Mostafa Kamal	GIS Analyst
22	Nasreen Islam Khan	GIS Analyst
23	Nazmul Alam	GIS Specilaist
24	P.A. Khaleda Huq	GIS Analyst
26	Shameema Nasreen Mili	GIS Technical Assistant
27	Shamsuddin Ahmed	GIS Specialist
28	Sultana Dilruba Aziz	GIS Management Consultant
29	Syed Iqbal Khosru	GIS Specialist
30	Syed M. Iqbal Ali	GIS Institutional Advisor

Appendix B

List of Short-Term Expatriate Consultants

1. Brett Bundock
2. Brian Tittley
3. David Horwood
4. David Savory
5. Dirk Werle
6. Hugh Brammer
7. Kathleen Hastings
8. Kirk Kuykendahl
9. Kumar Royan
10. Mead Allison
11. Mike Pooley
12. Scott Bartling
13. Steven Keuhl
14. Thomas (Jay) Hart
15. Timothy C. Martin
16. Tom Chidley
17. Tom Schwartzman
18. Tom Wagner

Appendix C

Computer Resources of FAP 19

HARDWARE

Microcomputers:
- 1 486DX2/50
- 2 486DX/33
- 3 386DX/33
- 1 386/25
- 2 386SX/25
- 8 486DX/33 (rental)

Graphic Display:
- 2 17" SVGA monitors
- 2 20" RGB monitors 1024x1024
- 2 32bit image processors, Imagraph

Hardcopy Output:
- 1 HP Laserjet III
- 6 dot-matrix printers
- 2 Tektronix color inkjet
- 1 Tektronix Phaser II thermal wax
- 1 Calcomp A0 8-pen plotter

Hard Drive Capacity:
- 6.490 gigabytes
- 382 MB average

Other Mass Storage:
- 3 Colorado Memory System Jumbo 120 MB
- 2 Colorado Memory System Jumbo 250 MB
- 9-track 6250bpi tape drive, Ciper

Digitizing Tables:
- 2 Calcomp 36x48

Network:
- 10 nodes of Lantastic NE2000

SOFTWARE

GIS vector packages:
- PC ARC/INFO 3.4D+(9 keys + 6 for training)
- PC ARC/INFO for Windows (3keys)
- PC TIN 2.2 (1 key)
- Arcview1 3.5

GIS raster packages:
- PC ERDAS 7.5 (2 keys)

VGA ERDAS 7.5 (3 keys)
- ERDAS IMAGINE 8.1
- Earthview 4.0 (1 key)
- IDRISI 4.1
- Surfer for Windows
- IDA 4.0

IMAP 1.28
- Geographic Calculator 2.0

Operating Systems/ Environments:
- MSDOS 6.22
- Windows 3.11
- Windows NT 3.5
- QEMM 7.0

Other Analysis Packages:
- Dbase IV 1.5

QAPlus 4.75

CA Clipper 5.2
- R+R Report Writer 5.0
- Quattro Pro 5.0
- Lotus 123 2.2

Sundry Tools:
- Wordperfect DOS 6.0
- CorelDRAW 5.0
- Deluxe Paint II Enh 2.1

Utilities:
- PKZIP 2.04
- Superprint 3.01
- Lantastic 6.0
- PCTools 7
- Norton Utilities 8.0
- Norton Anti-virus 3.0
- AMI Diagnostics 4.0

Appendix D

FAP 19 Digital Data Resources

National Database

- National, district, thana boundaries
- Urban and agricultural land use
- Soil association, physiography, moisture zones, thermal zones, floodplain age
- Hydrography: rivers, beels and chars
- Infrastructure: roads and railways
- Hydrometric stations: water level, discharge and rainfall measuring stations
- Land type (flood extent and depth) derived from soils and DEM analysis.
- Flood forecasting schematics with macros for "real-time" simulations.
- Demography: Thana population data, literacy and household income

Tangail Area Data of 10,000 ha of FAP 20 Compartmentalization Area including

- administrative units: thana, union mauza
- embankments, roads and drainage
- habitat, soils and seasonal management implications

Disaster Management Pilot

- Mostly coastal thanas of Banshkali and Sitakunda
- mauza level detailed base map
- risk zones
- populations
- shelter locations and catchments
- roads, godowns, community centers, and embankments

DEMs and Modelling Derivatives

- Digital Elevation Model (DEM): national and regional - 500m and 1km resolution
- Local DEMs (Tangail, North Central, Southwest, Atrai, Gumti), along with some associated soil and rainfall data.

River Morphology and Charlands

- Jamuna River Dynamics (bankline, char width, centerline, and channel changes) many socioeconomic and vegetation attributes built on mauzas, bend analysis and mass balance input data, historical map comparison.
- Image processing, vector and socioeconomic results on Ganges, Padma and Meghna rivers.
- Detailed river network for Sundarban area.
- River alignments from 1:50,000 scale Spot satellite images, national coverage.

Sedimentation Study

- Physographic units, relative age of floodplains, DEM, inundation land types, soil association
- Jamuna left bank alignment from 1830-1994
- Annual suspended sediment, CS_{137} inventory, sediment transport balance
- Hydrography, infrastructure

Satellite Imagery

- 23 geo-referenced digital scenes or sub-scenes from Landsat, SPOT, ERS-1
- 58 uncorrected digital scenes as original data.
- 4 radar scenes (ERS-1) orginal data.

EIA Training and Case Studies

- 5 diskettes of training-oriented example data prepared in support of the Environment Study (FAP 16).

Appendix E

List of Technical Notes, Reports and Documents Prepared by FAP 19

REPORTS

GIS Resources in Bangladesh (Jun 91)
Inception Report (Aug 91)
Interim Report (Dec 92)
GIS Institutional Issues (July 93)
Final Report (June 95)

TECHNICAL REPORTS

Classification of Flood Depth and Extent Using Mike 11 and GIS (Feb 93)
Comparison of Elevation Data from BWDB and Finnmap (Jan 93)
GIS Technology for Disaster Management Pilot Study Interim Report (Apr 94)
GIS Mapping of BWDB Flood Forecasting Data (Apr 94)
Bangladesh National Digital Elevation Model (May 95)
Bangladesh National Level GIS Database (May 95)
A Study of Sedimentation in the Brahmaputra-Jamuna Floodplain (June 95)
Satellite Based Radar for Flood Monitoring in Bangladesh (June 95
GIS Potential for IFFD: A Case Study of Manikganj (June 95)

TECHNICAL NOTES

No. 1 Bangladesh Transverse Mercator Projection (May 92)
No. 2 North Central Region Digital Elevation Data (Jan 93, Aug 93)
No. 3 Area Elevation Curves for BWDB Southwest Regional Projects (Jan 93)
No. 4 GIS Atlas for Tangail Area Study (Nov 92)
No. 5 Bangladesh GIS Installation Summary (Oct. 94)
No. 6 Tangail Area Digital Elevation Model (Aug 93)
No. 7 Bangladesh National Digital Elevation Model (Aug 93)
No. 8 National Database for Bangladesh (Aug 93)
No. 9 A Semi-Detailed River Database for Bangladesh (Mar 95)

TRAINING MANUAL

Introduction to GIS and Remote Sensing in Environmental Impact Assessment (Aug 93)

ARCHIVE DOCUMENT

Archive of GIS Database and Project, Vol. I,II & III

COLLABORATION REPORT WITH FAP 16

- EIA Case Study: Compartmentalization Pilot Project (Dec 92)
- EIA Case Study: Bhelumia Bheduria Project (Apr 93)
- The Dynamic Physical and Socioeconomic Environment of Riverain Charlands: Jamuna (Aug 93), Meghna (Oct 93), Ganges (Oct 93), Padma (Oct 93)

Appendix F

Summary of FAP 19's Assistance to other FAP Projects

FAPs	Type of assistance provided
FAP 1	Images and maps of Jamuna River near Sariakandi
	Color prints of Jamuna River bankline study
	Collaborative study of Jamuna River
	Images of Jamuna River banklines
	Images of Jamuna riverbank erosion
	Graphs showing rate of change of width of the Jamuna
FAP 2	Data from National GIS Database
	Image of 1987 flood for North West Region
FAP 3.1	Landsat imagery of Jamalpur area
FAP 4	Collaboration on digital elevation modeling
	Findings and recommendation of flood depth modelling
	Data on flood depth modelling
FAP 5	Images of South East region
	Assessment of digital elevation data for use in the project
FAP 6	National digital elevation model (DEMII) data
	Digital elevation model data, maps
	1973 Landsat image of Northeast Region (Sylhet area)
FAP 7	Satellite image maps
	Images of polder area in South East region Jan 1977
FAP 14	Maps for FAP 14 Reports
FAP 16	Maps and analysis for Charland Study
	Tangail Area and Bhelumia-Bheduria EIA Case Studies
FAP 17	Maps of North Central Regions
	GIS data for Tangail area, Status of National Database
	GPS results and cooperation on the Flood Management Model

	Findings and recommendation of Flood Depth Modelling
	Data: Sub compartment of crop capability, Gross area Landtype, water level, etc.
	DXF files from Arc/Info : Tangail compartment boundary coverage
	Upstream Flood Impact Assessment in Tangail Compartmentalization Pilot Project
	Image and maps of Sirajganj
	Historic satellite images of the Jamuna River
	Analysis of river bankline erosion
	Information on Geodetic Coordinate System
	Bathymetry maps on Jamuna River survey area
FAP 25	National Digital Elevation Model (DEMII) data
	Provision of reports and methodology for flood mapping for use in the Flood Management Model

Appendix G

Summary of FAP 19's Assistance to Organizations Outside of FAP

Organizations	Type of Assistance Provided
ACTIONAID	Jamuna Charland Study Report, maps, imagery etc. on the particular area in Jamalpur area
Bangladesh Center for Advance Studies (BCAS)	Cooperation for presentation of climate change vulnerability profile
	SPOT image with index and use of GPS
	National Database with Upazila Boundaries, MPO planning area boundary.
	Digitized map of Bangladesh with thana boundaries, 17 agro-ecological zone, MPO's flood depth maps.
Bangladesh Agricultural Research Council	Provision of soil associations (17 maps), Bangladesh maps with district and thana boundaries, roads, rivers, railways, monitored wells, water level and discharge stations, rainfall stations, digital elevation model, land use, population and demography.
Bangladesh Unnayan Parishad	Soil associations (17 maps), Bangladesh maps with district and thana boundaries, roads, rivers, railways, monitored wells, water level and discharge stations, rainfall stations, digital elevation model, land use, population density 1991 & 1981 thana wise and demography.
Bangladesh Bureau of Statistic (BBS)	Map of the household consumption survey data: a surface of calorie intake, a surface of expenditure on education of males and females.
Brandon University, USA	Landsat image on riverbank erosion and flood hazards
British Broadcasting Corporation (BBC)	Provision of maps and images for use in a documentary program on flooding
CARE International	Data of Land use type (DEM)
	Some assistance to IFFD Pilot project
	Data and map of Inundation Depths of Different Areas of Bangladesh
Center for Environmental and Resource Studies	Provision of DEM, interpolated rainfall data, vector files for international boundary, administrative districts and thana boundaries

Crop Diversification Programme	Digital data and images of Thanas used in study of fallow lands in RABI season study of CDP
	Image print out of Agroecological Zones at Thana level Raipur, Lakshimpur and Gazaria, Munshiganj
CPP Circle, WDB, Tangail	Map showing infrastructure, soil association, seasonal waterbody, wells, pond density
	Satellite images of coastal area 1973-1990
Food and Agriculture Organization	SPOT 1990 Images
	Use of Topo sheets 1:50,000
German Embassy Embassy of the Federal Republic of Germany	Charland data of Brahmaputra-Jamuna, Ganges. Meghna and Padma rivers
Helen Keller International	National level thana coverages
	Upazila coverage
HALCROW Consulting Engineers	Satellite images at Sariakandi,Mathurapara 1993, 1994
River Bank Protection Project	A Composite of the 1993 and 1994 images showing river bankline changes
Institute of Geography, Hallerstr, Berne, Switzerland	Reports materials on Jamuna River and Landsat images of the Jamuna River
International Institute and Aerospace Survey and Earth Sciences (ITC), Netherlands	GIS Data: National DEM, rainfall models, Landsat digital data of Padma-Meghna confluence
	GIS Data for several Thanas
International Center for Diarrhoeal Disease Research (ICDDRB), Bangladesh	Administration boundaries, rivers and roads databases
Jamuna Multipurpose Bridge Project	Landsat TM Image for the Jamuna River with mouza boundaries
John Snow International	Map on the network of highways in Bangladesh
Local Government Engineering Department	National coverages for administrative boundaries, rivers and roads

National Minor Irrigation Development Project	Digital elevation model, Land type data as derived from the DEM, Soil database as derived from the SRDI/LRAP, together with the associated software for interrogation
	Landsat TM data for path 138, row 43
Okabe Asami Laboratory Department of Urban Engineering, Japan	Arc/Info coverages of the coastal areas/thanas of Bangladesh
RADARSAT International	Radar data for use in developing promotional materials
Soil Testing, Management and Development of SRDI Project	Data from National Database for use in training in Denmark
	Toposoil texture database, Landsat TM Images of Jamuna River
	SPOT heights for the North Central Region as ARC/INFO point coverage and DEM Files
	Data of National Database
	SPANS digitized files from AST
Surface Water Modelling Center	GIS coverages: Rivers, Major Roads, Rails, Water Level and Discharge Stations, Rainfall Stations
	Digitized map of the Sundarbans in the SutoCAD DXF format for use in flood and salinity modeling
	GIS data in coordination with FAP 25 on Flood Management Model
	Sediment and Hydrometric Data
	Satellite Images for the Gorai River
University of Nottingham, UK	Landsat Satellite images for dry season (1973,76,78,84,87,90,92,94) and cumulative erosion maps of Jamuna
US Embassy, Map and Publications Section	Data from National GIS Database

Appendix H

List of Databases of FPCO/FAP 19 Cooperative Databank

THEME/LAYERS	ASSOCIATED ATTRIBUTE DATA	SOURCE MAP/ SCALE	DATA FORMAT
ADMINISTRATIVE BOUNDARIES			
Thana	Name, Geocode, BBS Census data	AEZ, 1:250 000	ARC/INFO
District	Name, Geocode, BBS Census data	AEZ, 1:250 000	ARC/INFO
National		SOB, 1:50 000	ARC/INFO
INFRASTRUCTURE			
Roads		AEZ, 1:250 000	ARC/INFO
Railways		AEZ, 1:250 000	ARC/INFO
Urban		AEZ, 1:250 000	ARC/INFO
HYDROGRAPHY			
Rivers	Name, Width class	SPOT Image Maps 1:50 000	ARC/INFO ERDAS
Beels	Name	SPOT Image Maps 1:50 000	ARC/INFO
Chars		SPOT Image Maps 1:50 000	ARC/INFO
SOILS and AGROECOLOGY			
Soil Association	Soil Series, Physical and Chemical parameters, Landuse with Interpretations	AEZ (BARC,SRDI) 1:250 000	ARC/INFO
Physiography	Physiographic unit i.d.	AEZ (BARC,SRDI) 1:250 000	ARC/INFO
Moisture Zones	Growth Period by Season	AEZ (BARC,SRDI) 1:250 000	ARC/INFO
Thermal Zones	Temperature by Season	AEZ (BARC,SRDI) 1:250 000	ARC/INFO
Floodplain Age	Relative Age	FAP19 Derived from AEZ Physiography map	ERDAS
LAND ELEVATION			
Digital Elevation Model (DEM)	Elevation (0.1 m units)	BWDB Contour Maps 1:7 920; 1:15 840	ERDAS
HYDROMETRIC STATIONS	Water level, Discharge, Rainfall Measuring Stations	BWDB Maps 1:750 000	ARC/INFO
DEMOGRAPHY	Thana Population Data, Literacy, Household income	1991 BBS Census Data	ARC/INFO
FLOOD REGIME			
Landtype	MPO Flood Classes (F0-F4)	FAP19 Derived From AEZ Maps and DEM	ERDAS

Appendix I

Number of Attendees in GIS Training Held Under FAP 19

Organization	Type of Training Course			
	GIS (ICIMOD)[1]	pcARC/INFO	ERDAS[2]	Special[3]
FAP 19/ISPAN		17	11	17
FAP 16/ISPAN		1		
FAP 2		1		
FAP 4		1		
FAP 10				1
FAP 17	2			
FAP 20		3		1
FAP 21/22		1		1
FAP 24				2
FAP 25		1		2
FPCO	3	5	1	8
BWDB		5		6
WARPO		2		
MoIWDFC (MoWR)	1			1
IMED				1
SPARRSO		2		22
BBS		3		2
DOE		1		
SOB		1		2
LGED		1		1
BARC		2		
SRDI				2
BMD				2
DMB				2

Organization	Type of Training Course			
	GIS (ICIMOD)[1]	pcARC/INFO	ERDAS[2]	Special[3]
SWMC				2
NMIDP		1		1
CDP				3
FAO/UNDP				1
CDA		2		
CARE		4		1
DANIDA				1
ICDDRB				1
BCAS				3
BCL		1		
CIPROCO		2		
DPC		1		
Mott MacDonald		1		
BUET				5
Rajshahi University		1		
TOTAL	**6**	**60**	**12**	**91**
GRAND TOTAL	**169**			

GIS (ICIMOD)[1] a special Introductory two-week GIS course held at ICIMOD, Nepal and sponsored by FAP 19/ISPAN

ERDAS[2] includes pc and VGA ERDAS as well as raster GIS and Image processing

Special[3] includes pcTIN, Radar Remote Sensing, Training of Trainers, and EIA-GIS Study Tour

Appendix J

DETAIL OF GIS & RELATED TRAINING

Training Name	Date/Duration	Organization	Participants	Trainer	Description
pcARC/INFO	October, 1991	FAP 19	I.G. Chowdhury Ahmadul Hassan Chapal Chowdhury Hasan Ali Iffat Huque Shamsuddin Ahmed Nazmul Alam	Kumar Royan	Initial Introductory course on pcARC/INFO
ERDAS	December, 1991	FAP 19	I.G. Chowdhury Ahmadul Hassan Chapal Chowdhury Hasan Ali Iffat Huque	Jay Hart	Introductory course on raster GIS using ERDAS system
pcTIN	January, 1992	FAP 19	I.G. Chowdhury Ahmadul Hassan Chapal Chowdhury Hasan Ali Iffat Huque Shamsuddin Ahmed Nazmul Alam	David Horwood	Digital Terrain Modelling using pcTIN, 3-D view, slope analysis, etc.

Training Name	Date/Duration	Organization	Participants	Trainer	Description
Raster GIS & Image processing	10, 12, 14 March, 1992	FAP 19 FAP 19 FAP 19 FAP 19 FAP 19 FAP 19 FAP 19 FAP 19 FAP 19 FAP 19 FPCO	Ahmadul Hassan Iffat Huque Hasan Ali Chapal Chowdhury Shamsuddin Ahmed Nazmul Alam Aneeqa Shireen Syed Pia A. K. Huq Nasreen I. Khan Shamima Nasreen Mili A. Noor	Jay Hart	In-house introductory course on raster GIS and image processing
GIS (ICIMOD)	20-30 April, 1992	MoIWDFC FPCO FPCO FPCO FAP 17 FAP 17	Zinaida Irfat Delwar Hossain Md. Masud Khan Md. Abdun Noor expat. consult. expat. consult.	ICIMOD & FAP 19 - Tim Martin	Principles of GIS and digital mapping, overview of raster and vector systems with hands on exercises using pcARC/INFO and IDRISI with examples from Bangladesh digital datasets.
pcARC/INFO	1-12 November, 1992	FAP 19 FAP 19 FAP 19 FAP 4 FAP21/22 FPCO FPCO CARE CARE CARE DPC CIPROCO	Aneeqa Shireen Syed Nasreen I. Khan Syed I. Khosru Tony Green Quazi Saifuddin M. Masud Ahmed M. Siddiqur Rahman Steven Nakashima Mamunul H. Khan Wahid Murad Mir Abdul Matin M. M. R. Chowdhury	Brett Bundock	Basic training on pcARC/INFO with hands -on exercises and workshops on FAP 19 data and overviews on raster GIS and image processing

Training Name	Date/Duration	Organization	Participants	Trainer	Description
pcARC/INFO	2-14 December, 1992	FAP 19 FAP 19 FAP 19 FAP 2 FAP 25 FPCO FPCO SPARRSO Mott MacDonald CIPROCO	Pia A. K. Huq Mostafa Kamal Matin Miazi Ehsan H. Chowdhury S. Nawazish Noman M. Shahjahan S.M.S. Mahmood D.A. Quadir Manirul Haque M. Nahid Mostafa	Kumar Royan	Basic training on pcARC/INFO with hands -on exercises and workshops on FAP 19 data and overviews on raster GIS and image processing
Radar Remote Sensing	11-12 June, 1994	FAP 19, BWDB, FPCO, FAP 10, FAP 20, FAP 21/22, FAP 24, FAP 25, SWMC, SPARRSO, DMB LGED , SOB, BMD, BBS, CDP, SRDI, DANIDA, BUET, NMIDP, BCAS, DOF, CARE, BUET, ICDDRB	about 100 participants	Dirk Werle Brian Tittley	A two-day training workshop highlighting the fundamentals of satellite-based radar remote sensing and its potential applications in Bangladesh with special emphasis on flood management aspects

Training Name	Date/Duration	Organization	Participants	Trainer	Description
EIA-GIS Study Tour	8 - 24 October, 1994	MoWR IMED/Plng Com DOE FPCO FPCO BWDB	M. Nazrul Islam Q.A. Quadir S.A.W.M. Wahed A.M. Shafi M.A. Noor M. Shahidul Islam	US Army Corps of Engineers	Six senior govt. officials of the water sector for learning the EIA process and GIS applications being used in the US so as to develop an appreciation for the utility of both EIA and GIS for potential applications in national, regional and local planning in Bangladesh.
Training of Trainers	23 Oct - 31 Oct, 1994	FAP 19 FAP 19 FAP 19 LGED	I.G. Chowdhury Iffat Huque Nasreen I. Khan Hasan Ali	Kathleen Hastings	Training of trainers in using pcARC/INFO for teaching the software to new users with comprehensive instructions and improve the presentation skills of the trainers
Introductory Course on pcARC/INFO	1 - 9 Nov, 94	FAP 19 FAP 20 FAP 20 FAP 20	Dilruba Aziz Bob Pengel Mehdi Hasan Shakeel Hasan	Kathleen Hastings I.G. Chowdhury Iffat Huque Nasreen I. Khan Hasan Ali	Basic training of GIS trainers using pcARC/INFO, with hands-on exercises
Introductory Course on pcARC/INFO	16 - 30 Mar, 1995	BWDB BWDB BWDB BBS BBS LGED DOE SPARRSO	Yasmin Begum Motaher Hossain ATM Khaleduzzaman Geiasuddin A. Bhuiyan M. Emdadul Haque Shakir Ahmed Mahmood Hasan Khan M. Fazlul Haque	I.G. Chowdhury Hasan Ali Iffat Huque Nasreen I. Khan	Basic training on GIS using pcARC/INFO, with hands-on exercises on applications using FAP 19 data, and overviews on raster GIS and image processing

Training Name	Date/Duration	Organization	Participants	Trainer	Description
Introductory Course on pcARC/INFO	16 - 27 April, 1995	BWDB BWDB SOB WARPO BARC CARE CDA CDA Rajshahi University	Syed Ismail Ali M. Harun ur Rasheed M. Shahinur H. Islam Md. Abdul Baten M. A. H. Chowdhury Ivor Melmore Ferdousi Begum Neaz Rahman Latifur Rahman Sarkar	I.G. Chowdhury Hasan Ali Iffat Huque Nasreen I. Khan	Basic training on GIS using pcARC/INFO, with hands-on exercises on applications using FAP 19 data, and overviews on raster GIS and image processing
Introductory Course on pcARC/INFO	15 - 29 May, 1995	FPCO WARPO FAP 19 FAP 19 FAP 19 FAP 16 BBS BARC NMIDP BCL	Md. Abdun Noor Md. Aminur Rahman Md. A. Malik Faruq Md. Mominul Haque Golam Monowar Kamal Md. Jakariya Md. Khorshed Alam Md. J. U. Chowdhury Md. A. Motaleb Sarkar Dr. Md. Nazim Uddin	I.G. Chowdhury Hasan Ali Iffat Huque Nasreen I. Khan	Basic training on GIS using pcARC/INFO, with hands-on exercises on applications using FAP 19 data, and overviews on raster GIS and image processing