BANGLADESH FLOOD ACTION PLAN

Ministry of Water Resources

Flood Plan Coordination Organization (FPCO)

Bangladesh National Level GIS Database

May 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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ACKNOWLEDGMENTS

This report is the result of a team effort by all of the FAP 19 staff. Since the inception of FAP 19 in 1991, team members have taken part in data acquisition, data enhancement, spatial analysis, and map production to create what is today the FAP 19 National Database. These efforts are ongoing and additions and improvements to the database will continue beyond the publication of this report.

Following is an alphabetical list of those responsible for compiling and producing the National Database: Shamsuddin Ahmed, Hasan Ali, Nazmul Alam, Dr. Iftekhar Ghani Chowdhury, Abdul Malik Faruq, Pia Afreena Khaleda Haq, Ahmedul Hassan, Mostafa Kamal, Nasreen Islam Khan, Syed Iqbal Khosru, Kirk Kuykendal, Matin Miazi, Dr. Mike Pooley, David Savory and Aneeqa Shireen Syed. The report was written by David Savory, Timothy Martin, Matin Miazi, Dilruba Aziz, Aneeqa Shireen Syed and Nasreen Islam Khan, and edited by Carol Jones. The National Database Project was initiated and coordinated by Timothy Martin, FAP 19 Team Leader.

The National Database Project could not have been possible without the support and coordination of numerous organizations in Bangladesh, particularly that of the Flood Plan Coordination Organization (FPCO). Other organizations include: the Agriculture Sector Team (AST) project, Bangladesh Agricultural Research Council (BARC), Bangladesh Bureau of Statistics (BBS), Bangladesh Water Development Board (BWDB), Surface Water Modeling Center (SWMC), and numerous projects of the FAP.

GLOSSARY

AAT	-	Arc Attribute Table
AEZ	-	Agroecological Zone
AST	-	Agriculture Sector Team
BBS	-	Bangladesh Bureau of Statistics
beel	-	Bangla term for an area of open water away from a river
BIWTA	-	Bangladesh Inland Waterways Transport Authority
BTM	-	Bangladesh Transverse Mercator
BWDB	-	Bangladesh Water Development Board
CIDA	-	Canadian International Development Agency
CPP	-	Compartmentalization Pilot Project (FAP 20)
DEM	-	Digital Elevation Model
district	-	A large administration unit under the authority of a Deputy Commissioner, now known as a zila
FAO	-	Food and Agriculture Organization
FAP	-	Flood Action Plan
FFWD	-	Flood Forecasting and Warning Division
GIS	-	Geographic Information System
homestead	-	Settlement area
khal	-	Bangla term for a drainage channel or canal either natural or man-made
kharif	-	Summer/wet season
LGED	-	Local Government Engineering Division
mauza	-	A village revenue collection and cadastral mapped unit
MPO	-	Master Plan Organisation (of Ministry of Irrigation Water Development and Flood Control)
NGO	-	Non-Government Organization
NMIDP	-	National Minor Irrigation Project
PAT	-	Polygon or Point Attribute Table
PWD	-	Public Works Department
SOB	-	Survey of Bangladesh
SPANS	-	Spatial Analysis System
SPARRSO	-	Space Research and Remote Sensing Organisation
SPOT	-	System Pour Observation de la Terre
SRDI	-	Soil Research Development Institute
SWMC	-	Surface Water Modeling Center
thana	-	A sub-division of a zila, or district, formerly known as upazila
TM	-	Thematic Mapper
UNDP	-	United Nations Development Programme
union	-	Subdivision of a thana
WARPO	-	Water Resource Planning Organization

1. Introduction and Objectives

This National Database Project was undertaken to provide a geographic information system (GIS) facility to assist in planning and managing geographic information for the Flood Action Plan (FAP) in Bangladesh, and to promote standardized data protocols and database formats. It is hoped the database will provide unrestricted access to water resources management and planning information for legitimate users. The national scale data is useful at regional and sub-regional levels for display and mapping, as well as for spatial analysis.

Objectives for the National Database Project were:

- To provide a GIS database for archiving, managing, analyzing, and presenting spatial data and associated geographic information for the FAP.
- To establish and promote standardized spatial data protocols and database formats in areas important to water management planning.
- To enhance existing spatial databases by linking nonspatial attribute data with geo-referenced data.

The National Database Project consists of spatial data compiled and digitized as part of FAP 19 GIS application projects and integrates data that previously existed in Bangladesh. Existing data collected from external sources was reformatted, edited, and updated to provide an integrated GIS with a consistent data protocol.

Data categories produced by FAP 19 includes rivers and *beels*, topography,the national boundary, water resource monitoring stations, groundwater information, and census information. Data categories originally acquired externally and then substantially modified for standardiztion includes soils, roads, railroads, and thana and district boundaries. A third data category consists of by-products generated from the above mentioned primary data sources. For example, a digital map showing average flood depth was created through the integration of soils and topographic information using GIS spatial analysis. Thus, the National Database is an expandable data set that has the potential to grow not only through data input, but as a consequence of its use.

The database was organized at national and regional levels to accomodate the different spatial scales used by the FAP. FAP 19 also generated a number of specialized databases at regional and local scales. All data layers can be produced at a scale of 1:250,000 or smaller, and some select data categories can be mapped as large as 1:50,000. Section 3 of this document summarizes the contents and source of the database categories, while Appendix-1 describes the digitizing methodology, lineage, and specifications of each category.

2. GIS Software and Data Protocol

The digital format and quality standards of GIS databases determines how useful they are for data sharing among projects and organizations. FAP 19 has held numerous discussions and meetings with GIS users to determine their data needs and preferred formats. The main GIS software packages selected for use by

FAP 19 are the vector-based pcARC/INFO[1] (Version 3.4D Plus) GIS and the raster-based PC ERDAS[2] (Version 7.5) GIS. These GISs are widely used internationally, and ARC/INFO is common in Bangladesh.

The data structure used to store digital maps in ARC/INFO is known as a "coverage." A coverage is an automated map that contains sets of points, lines, or polygons which represent geographic features and their associated attribute data. For example, a soil map would consist of polygons representing soil map units, each with a unique identifier (user-id) which ties it to a record in a database table containing descriptive attributes. These database tables are known as Point or Polygon Attribute Tables (PAT) when describing points or polgyons, respectively, and Arc Attribute Tables (AAT) when related to lines. The coverage in ARC/INFO is actually stored as a directory of files on a computer's disk. These files, which include the PAT and AAT, each contain specific information about the coverage. Henceforth, the term coverage will generally be used in this context.

ERDAS, on the other hand, employs a "raster" structure in which data is laid out in a grid and each cell is represented by a display pixel. A data file value is assigned to each pixel to represent a map attribute, for instance, the user-id for a specific soil type can be assigned to pixels which coincide with each soil map unit polygon. Raster data generally are stored in one of the two following types of ERDAS files:

- *GIS* files typically contain data file values that represent qualitative information such as soil type, vegetation type, percent slope, or polititical unit. This information is stored as *8-bit* data, i.e., each pixel consumes one byte of computer disk space.
- *LAN* files usually contain data which represent surface images acquired from satellite, aircraft, or photographic remote sensing. They also may consist of elevation data representing topographic surfaces. This information is stored as *8-bit* or *16-bit* data, i.e., each pixel consumes one or two bytes of computer disk space, respectively.

All layers of the FAP 19 National Database are maintained in at least one of the data formats described above. Both ERDAS and ARC/INFO software packages allow extensive interchange with other commonly used formats. Appendix-2 lists some of the file format conversions which are possible from these GISs.

"Bangladesh Transverse Mercator Projection," the first in a series of FAP 19 Technical Notes (1992), proposed the adoption of a standard mapping projection for all digital mapping within the FAP. The system recommended was a modified transverse mercator projection known as the Bangladesh Transverse Mercator (BTM), which is now part of the standard protocol for the FAP 19 National Database. Some FAP and associated organizations also adopted the BTM projection, thereby facilitating the exchange of digital information. All layers of the FAP 19 National Database are currently maintained in BTM, however, transformation to other projections remains an option. For further information on the BTM projection refer to the reprint of FAP 19 Technical Note No. 1 in Appendix 4 of this document.

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[1] Environmental Systems Research Institute (ESRI), Redlands, CA, USA

[2] Earth Resource Data Analysis Systems (ERDAS), Atlanta, GA, USA

3. Data Themes of the FAP 19 National Database

The National Database consists of data digitized as part of FAP 19 GIS application projects, digtial data acquired from other organizations and improved by FAP 19, and data derived from internal GIS analysis. Spatial data categories, or themes, created by FAP 19 include: hydrography, topography,the national boundary, water resource monitoring stations, groundwater information,and census data. The hydrography and topography themes are manifested in the rivers and Digital Elevation Model (DEM) databases, respectively, that were major FAP 19 GIS application projects and which consist of the most current national elevation and hydrographic digital data available in Bangladesh. The international boundary was digitized mainly to cartographically enhance map production. Water resource monitoring stations established by the Bangladesh Water Development Board (BWDB) were digitized as point features directly from BWDB maps. The groundwater data was originally acquired from the Water Resource Planning Organization (WARPO) to produce surface maps of hydrologic information. The census data was incorporated into the National Database in cooperation with the Bangladesh Bureau of Statistics (BBS) for producing thematic maps that depict the spatial distribution of demographic information.

Several of the National Database themes were originally digitized by the Canadian International Development Agency (CIDA)-funded Agriculture Sector Team (AST) project. They were digitized from a series of agroecological zone (AEZ) source maps that were published in the Land Resources Appraisal of Bangladesh for Agricultural Development in Report 5, Volume II by the United Nations Development Programme-Food and Agriculture Organization (UNDP-FAO). Data categories were acquired as a series of GIS files containing soils, roads, railroads, and administrative boundary features. However, most of these data were not initially usable in this national-level GIS as they required extensive reformatting, geo-referencing, and editing before they were mosaiced into single, seamless coverages with a consistent format and protocol.

The content and source of the data categories, or themes, is shown in Table 1. Additional information on these data layers can be found in Appendix 1, in which digitizing methods, data processing, and final data specifications are provided.

3.1 Administrative Boundaries

Administrative boundaries for thanas, districts, and the national boundary of Bangladesh are included in this data theme. ARC/INFO coverages containing thana and district boundaries delineate two important internal Bangladesh administrative units. Both have line features encoded as thana, district, and international boundaries, and coast line/island/*char* margins. As is characteristic of GIS data, the lines that compose the boundaries can be virtually assembled into polygon features, each with their own PAT. With this data structure in place, socioeconomic data can be related to either thana or district map units for display or analysis. Currently the thana and district PATs are linked to BBS census data as discussed further in Sections 3.7 and Appendix 1-A1.7. Thana headquarters are in a separate ARC/INFO coverage and are encoded as polygon features. The data were digitized by the AST project using TYDAC SPANS (Spatial Analysis System), a raster GIS. FAP 19 converted these data into ARC/INFO, subsequently integrating the 17 AEZ coverages into the national coverages (Figure 1).

The international boundary of Bangladesh is the template which delineates the spatial extent of the National Database. The inland boundaries are stable where they are bounded by topographic features such as the

Table 1 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 [3]	Reference Moisture Zones, Thermal Zones	Growing Period, Temperature	AEZ Maps; 1:750,000
Regional/Local Data Sets	Various	Groundwater, Census, Environmental, Socioeconomic	Various

Chittagong Hill Tracts. However, the constant shifting of the banks of the Ganges river make the boundary with India less clear. Similarly, the dynamic Meghna River delta coastal regions are difficult to bound accurately. The evolving form of the riverine and coastal *chars* further complicates the border situation. In an effort to pinpoint these ambiguous features, FAP 19 digitized the boundaries from the most authentic and current source available: Survey of Bangladesh (SOB) maps. These 15' x 15' maps were published at 1:50,000 scale and show natural resource and infrastructural themes covering the entire country. Though the information of these maps is not completely up to date (1957 - 1990), it is the only source authorized by the government of Bangladesh. Therefore, the international boundary delineated represents an effort from the best available sources, but, there are no claims to its authenticity or authority. The digital product format for the national boundary is ARC/INFO line coverage. (See Appendix 1 for further information.)

3.2 Infrastructure

The road and railway networks which make up this data theme were derived from the 17 UNDP-FAO AEZ maps (1:250,000 scale). The road network is not highly detailed and is intended for only national or regional use. It contains only major roads, such as national highways and primary, or type A, feeder roads. The Local Government Engineering Division (LGED) is currently digitizing more detailed road maps to include national highways, type A and B feeder roads, municipal roads, and some rural roads (see Section 5). The railway maps include major commuter and industrial lines. Both coverages exist in ARC/INFO format as line coverages (Figure 2). (See Appendix 1 for further information.)

[3] These data were added to the National Database just prior to publication of this report.

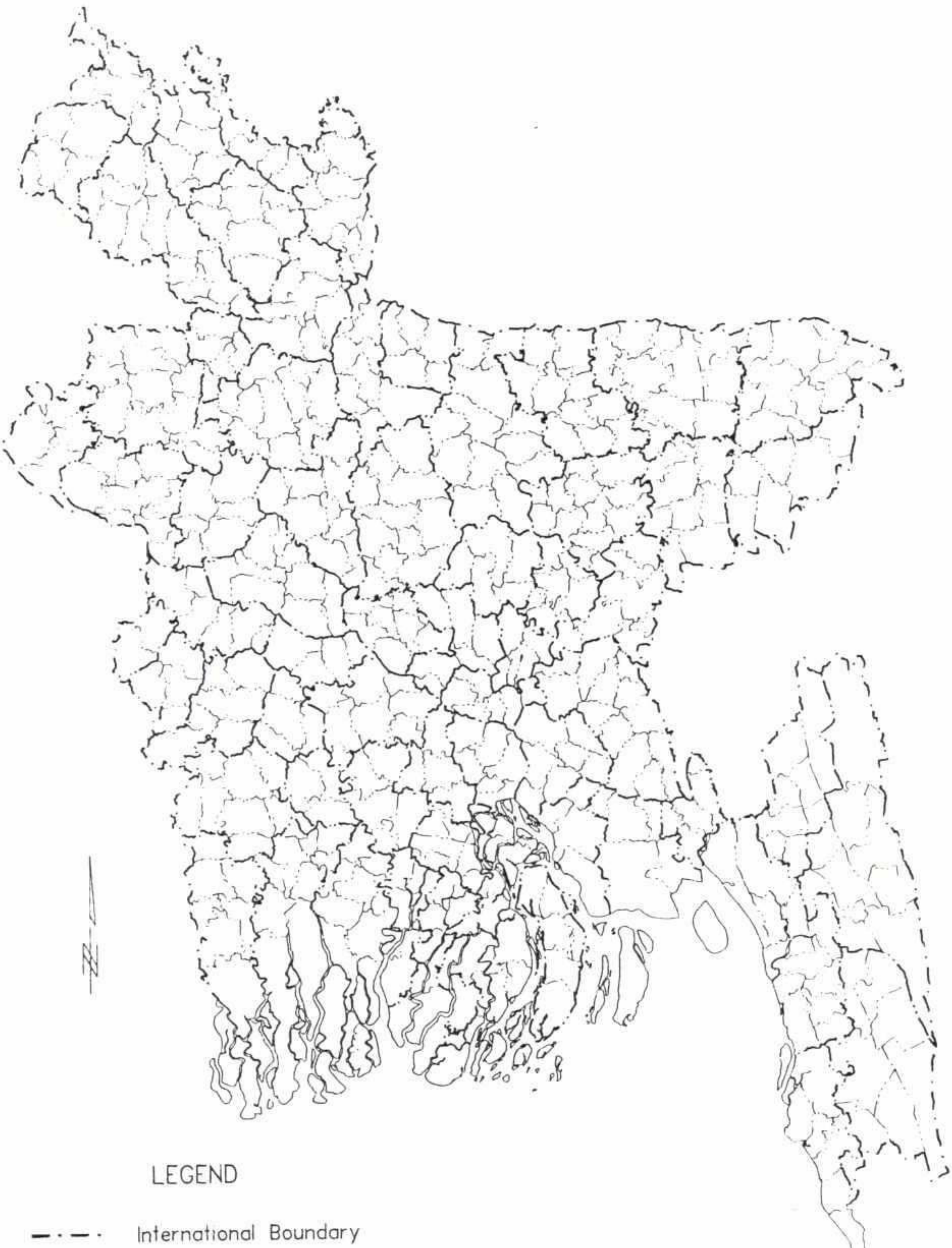

Figure 1 - Administrative Boundaries: Thanas, Districts, International

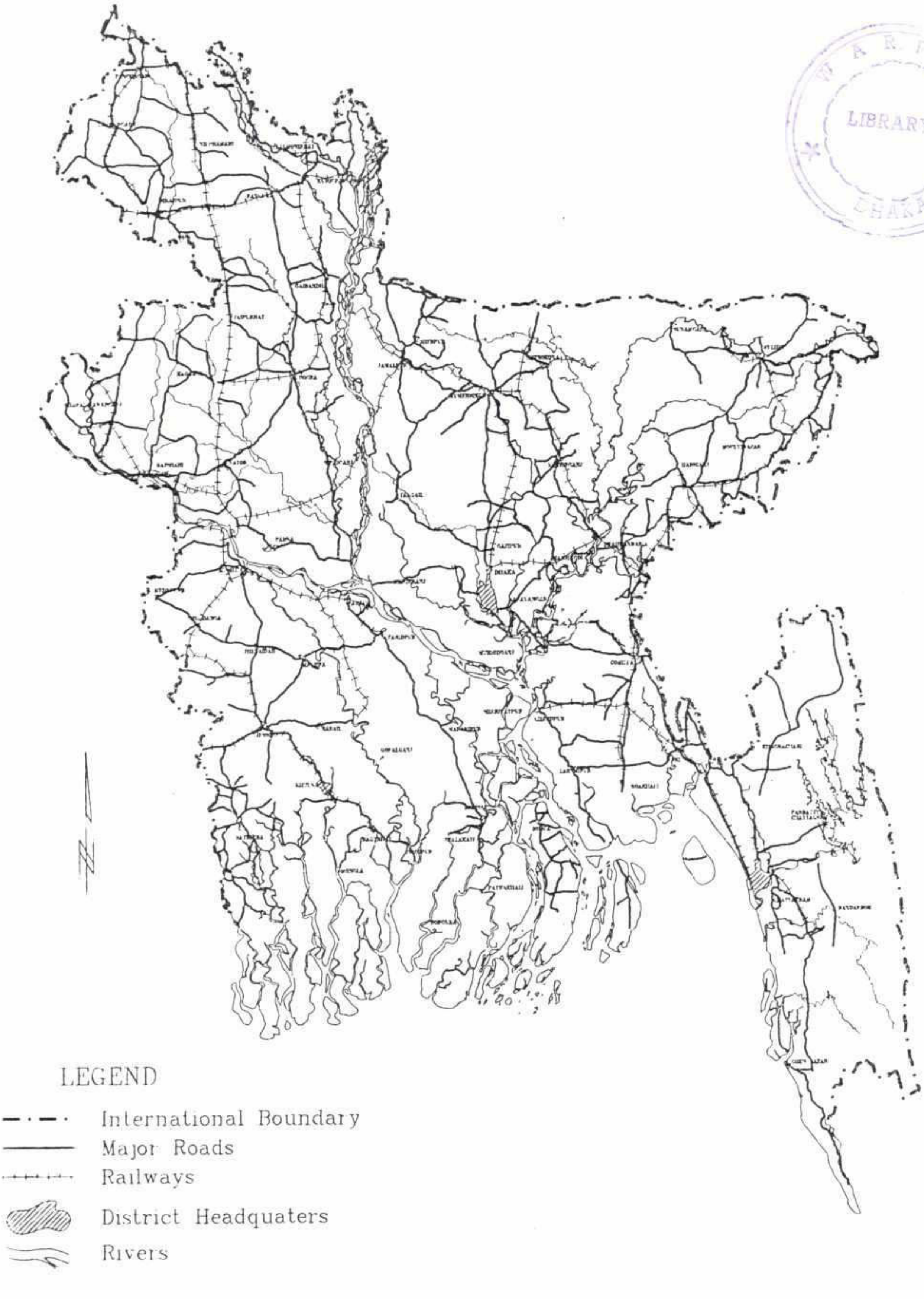

Figure 2 - Infrastructure: Roads, Railways, District Headquarters, Major Waterways

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3.3 Hydrography

Bangladesh is crisscrossed with numerous rivers and *khals* (streams) that form complex and dynamic river systems. The socioeconomic condition of Bangladesh is largely shaped by this riverine landscape that plays a vital role in the lives and livelihoods of its people. Proper management of these river systems is essential to sustain the country's agricultural and natural resources. A digital/spatial river database for Bangladesh, supported by GIS technology was developed for use in studies of river morphology, flood management, floodplain sedimentation, and other environmental and engineering related applications.

The original spatial database of rivers derived from the UNDP-FAO maps only recorded major rivers, and those only at low resolution because of the small-scale source maps. Nevertheless, these data have been archived as part of the National Database. However, because a more accurate and detailed rivers database was desirable, FAP 19 developed a new semi-detailed rivers coverage based on SPOT multispectral satellite image maps (compiled in 1989). These data were the most recent available and were at a larger scale and higher resolution than the AEZ maps. The SPOT image maps also provided more graphic detail on the rivers.

The SPOT maps were based on multispectral satellite images acquired in February 1989 at 1:50,000 scale with a ground resolution of 20 m. SOB topographic maps at 1:50,000 scale (compiled 1970s-1990s) were used chiefly as a reference in image interpretation. BWDB maps at 1:7920 and 1:15840 (compiled 1950s-1970s) also were used for image interpretation.

The data was digitized as line (narrow rivers) and polygon features (wide rivers, *beels*, *chars*, land masses) in ARC/INFO vector format. The river network database exists as four separate digital products (Table 2). The primary product was a line coverage which included all rivers, *chars*, and *beels* (Figure 3). Two accessory coverages also were created: a line coverage with narrow rivers (less than 50 m, 50-100 m) and a polygon coverage with wide rivers (more than 100 m), *chars*, and *beels*. In addition, a raster version of the river network was generated to afford greater versatility to the database and to enhance map production. It was produced by converting the ARC/INFO vector products to an ERDAS 8-bit raster file. The result is a digital semi-detailed river network for Bangladesh which includes rivers classified into three width categories, the dry season extent of *beels* and *chars*, and annotation for river and *beel* names. (See Appendix 1 and FAP 19 Technical Note No. 9 for further information.)

Table 2 FAP 19 River Data Products

File Name	Software Format	Data Structure	Content
Rivers	ARC/INFO	Vector Arcs	All rivers, river *chars*, coastal *chars*, *beels*
Riv_Poly	ARC/INFO	Vector Polygons	Rivers (>= 100 m wide), land mass, river *chars*, coastal *chars*, *beels*
Riv_Line	ARC/INFO	Vector Arcs	Rivers (< 100 m wide)
Rivers.GIS	ERDAS	Raster 8-bit GIS file	Bank lines, all rivers, land mass, river *chars*, coastal *chars*, *beels*

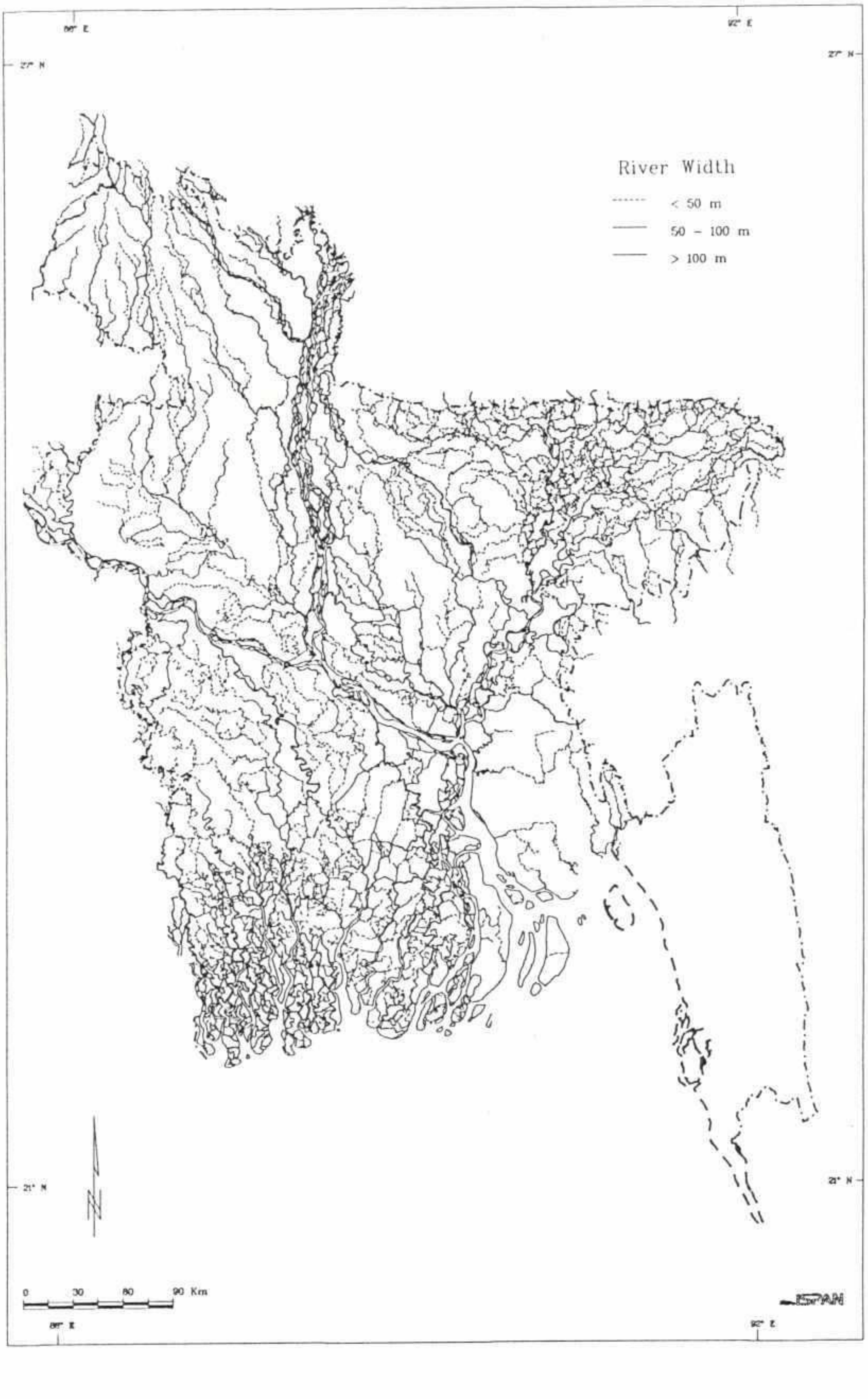


Figure 3 - River Systems

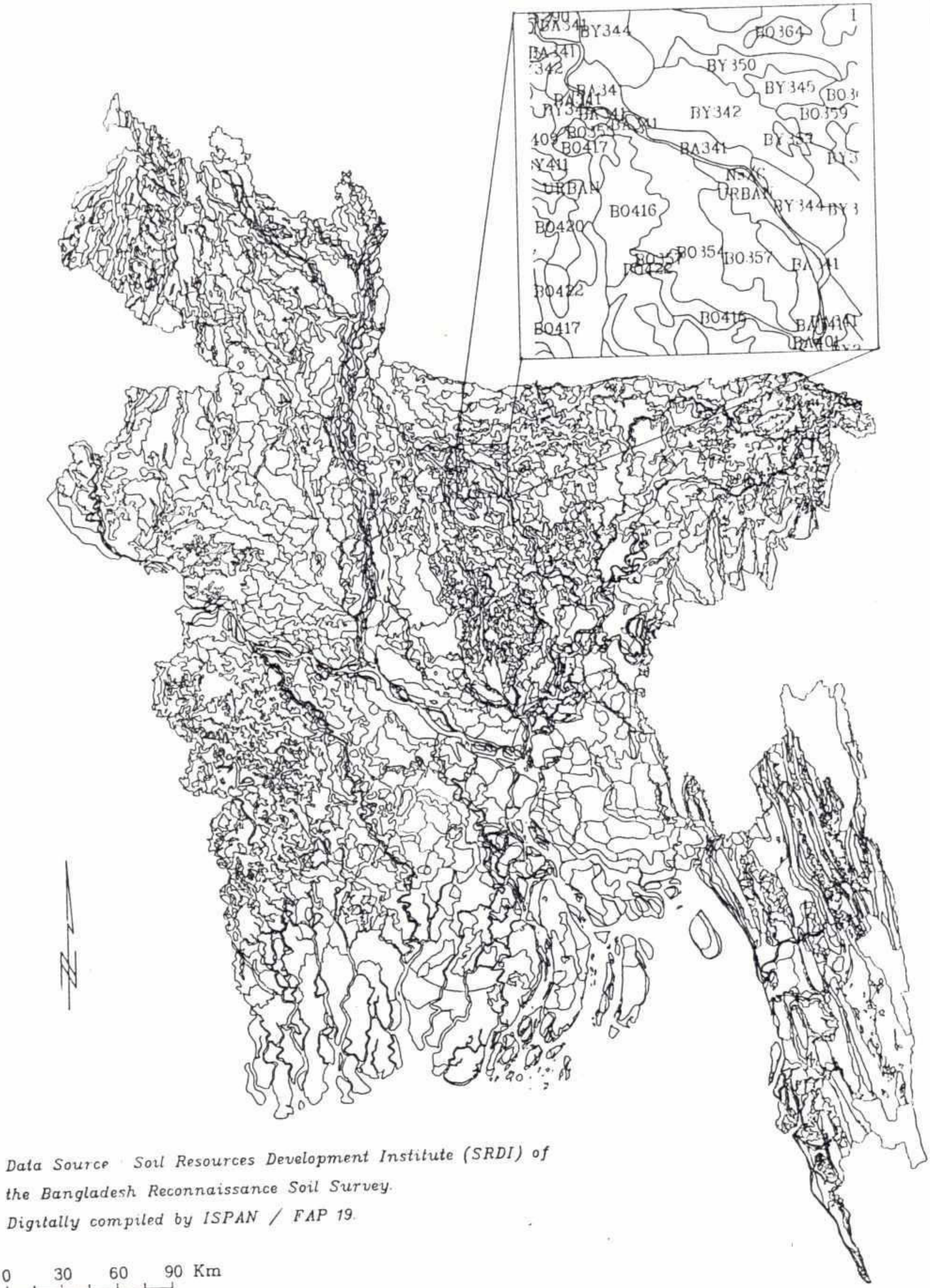
3.4 Soils

The soils data layer of the FAP 19 National Database is a key data theme with broad applications to agriculture, engineering, hydrology, urban and rural planning, and natural resources. Furthermore, the relational database linked with the digital map units is extensive and encompasses the entire nation of Bangladesh. Digitized soil association maps in SPANS format were acquired from the AST project for the 17 1:250,000-scale AEZ maps, each which represented a different agroecological zone. These maps were reformatted, geo-referenced, and edited to yield 17 ARC/INFO coverages which were ultimately combined into a national coverage (Figure 4). The national coverage was subsequently divided into five regional coverages: northwest, northeast, north central, southwest, and southeast. The AEZ Land Resources Appraisal also produced a group of agriculture-related tabular data sets intended for land evaluation purposes that included: soils, terrain, and flood regime characteristics. FAP 19 linked these data sets to the ARC/INFO soils coverages. This is the only national soils GIS data available in Bangladesh containing an attribute database.

AEZ soils data were derived primarily from the Reconnaissance Soil Survey conducted by the Soils Resource Development Institute (SRDI). Soils in this survey were mapped as members of a *soil association*, a group of distinct soils occurring contiguously in a regular pattern. The pattern is generally related to the landscape position (e.g., highland, medium highland, lowland) of the individual soils. Soil associations are specific mapping units that are unique within survey areas, but not necessarily among survey areas. A soil association may contain any number of different *soil series* formed in the same kind of parent material under similar environmental conditions. Soil series are further classified into *soil phases*, which are differentiated according to practical land use considerations. In Bangladesh, the most common type of soil phase is the depth of flooding classes: highland, medium highland, lowland. Other types of phases deal with flood duration, risk of flood damage, risk of riverbank erosion, slope, and salinity.

The soil phase is the most specific homogenous component of a soil association and the data included in the AEZ tabular land evaluation data sets were recorded at this level. Unfortunately, neither the soil series boundaries nor the soil phase boundaries were delineated on the AEZ maps. However, the area (hectares) of each soil series/phase within the soil associations were recorded in the land evaluation data sets. These data sets were originally acquired in spreadsheet format. FAP 19 converted the spreadsheets to dBASE IV format and modifications were made to the soil coverages to include these attributes in the PATs (Table 3). To determine the dominant series or phase for inclusion in the coverage PATs, a program called the FAP 19 National Database Toolbox was developed. With the Toolbox program, the percentage of soil association map unit area occupied by each class of a given soil property was calculated. The dominant class was determined and a corresponding field in the PAT was updated. Since the PAT is intrinsically linked to the soil association coverage polygons, thematic maps based on the soil properties can be generated using ARC/INFO. Note that the areas of homesteads (settlements), water bodies, and other miscellaneous land cover features were recorded separately and are excluded from the soil series/phase areas. The soil coverage PAT's include all of the AEZ attributes in Table 3 except for the area related fields: LANDAREA, HOMWATAREA, and MISLNDAREA.

Appendix 1 provides further information on digitizing methods, Appendix 3 details the SPANS to ARC/INFO conversion process, and a more detailed description of the soil properties and the algorithm for selecting dominance can be found in Appendix 5.



Data Source Soil Resources Development Institute (SRDI) of the Bangladesh Reconnaissance Soil Survey. Digitally compiled by ISPAN / FAP 19.

Figure 4 - Soil Associations

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Table 3 AEZ Land Evaluation Data Set

Spreadsheet Column	dBASE IV Field	Description
AEZCODE	SA	Soil Association Map Code
SERNUM	SN	Soil Series Number
VARNUM	SV	Soil Variant Code
PHASE	PC	Soil Phase Code
LANDTYPE	LT	Land Type (Inundation)
RELIEF	RE	Relief
SLOPE	SL	Slope
EROSION	ES	Erosion Status
TOPTEX	TX	Topsoil Texture
EFFDEPTH	SD	Effective Soil Depth
PAN	PP	Ploughpan
SOILMOIST	SM	Soil Moisture
PERM	SP	Soil Permeability
DRAIN	DR	Drainage
CONSIST	SC	Soil Consistency/Workability
REACTION	PH	Soil Reaction (pH)
NUTRIENT	NS	Nutrient Status
SALINE	SS	Soil Salinity
ALKALINE	AL	Alkaline Phase
CALCIC	CA	Calcic Phase
ACID	AS	Acid Sulphate Phase
FLOODEPTH	FD	Flooding Depth
FLOODHAZ	FH	Flood Hazard
EROSHAZ	EH	Erosion Hazard
SURGEHAZ	SH	Storm Surge Hazard
HAZFREQ	HF	Hazard Frequency
LANDAREA	LA	Land Phase Area
HOMWATAREA	HA	Homestead and Water Area
MISLNDAREA	MA	Miscellaneous Land Cover Area (details in Appendix 5)

3.5 Topography

A DEM is a computerized representation of a continuous surface, usually that of the Earth. More specifically, it is an array of digitally stored numbers representing the elevation of discrete points on a surface. This virtual surface can be viewed by displaying the array of values on a computer monitor with each point represented by one pixel. Since the elevation values are spatially referenced it is possible to apply mathematical algorithms to them for quantitative characterization of land surfaces. FAP 19 initiated a project to compile a medium-resolution (500 m x 500 m), or semi-detailed, DEM based on spot elevation points from BWDB topographic maps. The main objective of this project was to construct regional and national-level DEMs with horizontal resolution suitable for the automated terrain analysis and 3-dimensional terrain visualization as required by water resource, environmental, and engineering GIS applications.

A number of attempts have been made to produce regional and national DEMs in Bangladesh. During the 1980s, the Master Planning Organization (MPO) digitized a national level grid of elevation points (not a DEM per se) from BWDB topographic map data. The BWDB data was derived from a grid of spot elevations obtained by ground survey and photogrammetric techniques (100 m - 300 m spacing, 0.1 ft. altitude resolution), and presented on a series of topographic maps. The MPO elevation grid is based on interpreted BWDB elevation points and has 1 km horizontal resolution. In 1992, FAP 19 used ERDAS, a raster GIS (grid-based), to construct several DEMs based on the BWDB data (FAP 19 Technical Note Numbers 2, 6, and 7). These include regional DEMs constructed from the original spot elevation points and a national coverage derived from MPO's interpreted 1 km grid of elevation points. Although the 1 km DEMs are useful for regional and national level terrain visualization, their low horizontal resolution limits their usefulness for applications requiring quantitative terrain analysis. On the other hand, FAP 19's high resolution DEMs proved useful for a variety of GIS application projects. However, constructing them is time consuming and expensive, and the resulting data were excessively voluminous. Accordingly, FAP 19 produced a semi-detailed (500 m x 500 m), DEM based on generalized BWDB spot elevation points.

The BWDB topographic maps were compiled between 1952 and 1964 under the authority of the Surveyor General of East Pakistan. The topographic data consist of elevation points and contours, as well as information about important geographic features such as rivers, *beels,* forests, vegetation, homesteads, roads, and political boundaries. The land elevations points primarily represented agricultural land. Homesteads, forests, dense vegetation, and steep terrain generally were not included in the topographic survey, nor were areas rendered inaccessible by hydrographic features such as rivers or *beels*.

The BWDB maps were derived from several photographic bases and have a variety of cartographic specifications. They are compiled in two scales—4 in./mi. (1:15,840) and 8 in./mi. (1:7,920)—and have variable areal coverage. The elevation points are arranged on approximately 100 m x 300 m grids for the 4 in./mi. maps and 175 m x 175 m for the 8 in./mi. maps. The contours on both maps generally occur at one foot intervals and were derived from spot heights through manual interpretation or photogrammetric techniques. The FAP 19 team interpreted and digitized the spot elevation data from the BWDB topographic maps by manually superimposing a transparent 500-m grid template on the maps and recording the elevation point nearest each grid intersection. Data entry was expedited with an interactive database application program. The data was manually entered into a dBASE IV database file.

Following digitizing, it was necessary to adjust the values for datum differences, modify the elevation units, and convert these data from relational database files to ERDAS DIG file format. The final step in the DEM construction involved implementing a spatial interpolation algorithm for point-to-surface transformation, or, transforming the point elevation data acquired during digitizing into a virtual surface, i.e., a raster GIS file. A detailed account of this process is found in FAP 19 Technical Report "Medium Resolution Digital Elevation Model of Bangladesh".

The primary output from the entire DEM building process is in an ERDAS 16-bit GIS file. However, these files may be converted to any of several alternative formats for distribution or analysis. Three application programs using a high level programming language (C) were written to implement these conversions: Erd2Gen, Erd2xyz, and Erd2Surf. Erd2Gen creates a file suitable for input into the ARC/INFO GENERATE program which, in turn, can be converted to a point coverage. Erd2xyz creates a file with 3-dimensional point coordinates in x, y, z format for input to a spreadsheet program. Erd2Surf produces a file for use in SURFER, a surface mapping program. Data from the ERDAS file remains unaltered during these conversions.

Five primary DEM products were generated by this project: four with regional coverage (NE, NW, SE, SW) and one with nationwide coverage. These ERDAS GIS files have a 300-m pixel size and a 0.1-m elevation interval. It is important, however, to note that the data resolution of the products is dependant on the data source: 500-m horizontal resolution and 0.1-ft. vertical resolution. The national DEM is shown in Figure 5.

3.5.1 DEM Applications

The DEM products can be used for digital terrain analysis in a variety of environmental, engineering, and urban and rural planning applications. Digital terrain analysis is the spatial processing and graphic simulation of elevation data with the aid of a computerized GIS. GIS applications typically require DEM derivatives generated by using digital terrain analysis such as slope, aspect, contour, shaded relief, and 3-D perspective maps. Slope and aspect maps are color-coded to indicate the terrain's steepness and prevailing direction at each pixel, respectively. These maps are useful for planning, building roads and flood control structures, and environmental and natural resource modeling. Contour maps portray changes in elevation with a series of lines that connect points of equal elevation (as in the BWDB maps) and can be used for graphic representations of topography, or incorporated with other GIS data layers for modeling. Shaded relief maps depict variations in elevation based on user-specified sun angles. Map areas in the sunlight appear bright, and areas in shadow are shaded. These maps are generally used only as visualization tools for planning and modeling. Finally, perspective maps provide various 3-D views of landscapes from any number of viewing angles. The surface is generally represented by a "wire-frame" model (Figure 6). Aerial photos, satellite images, or GIS maps can be "draped" over the DEM to enhance such visualization.

These DEM-derived data layers in turn can be integrated with ancillary spatial data layers, such as satellite imagery, hydrography maps, soils maps, and land cover maps to serve many purposes. Practical applications of DEMs and their derivatives include:

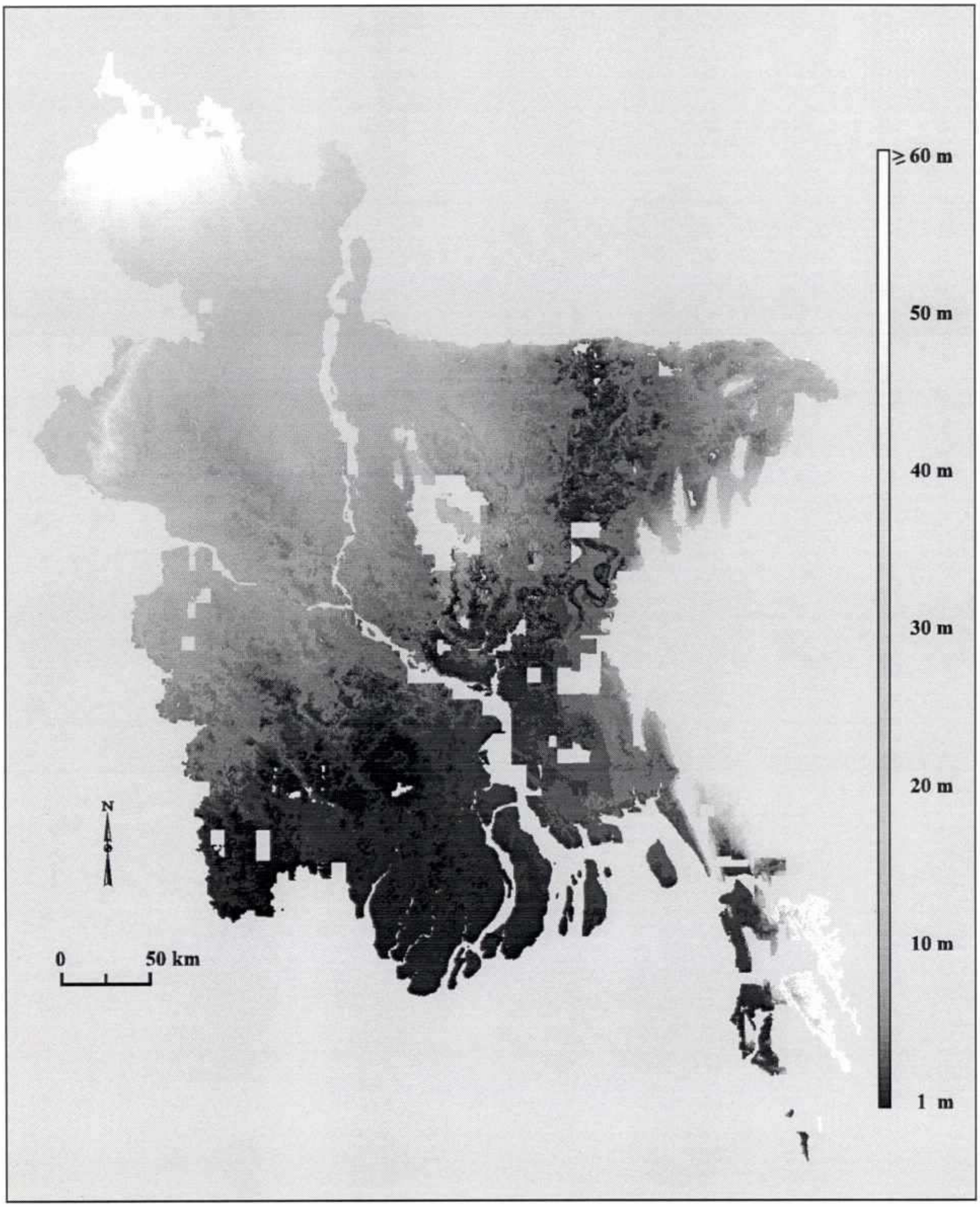
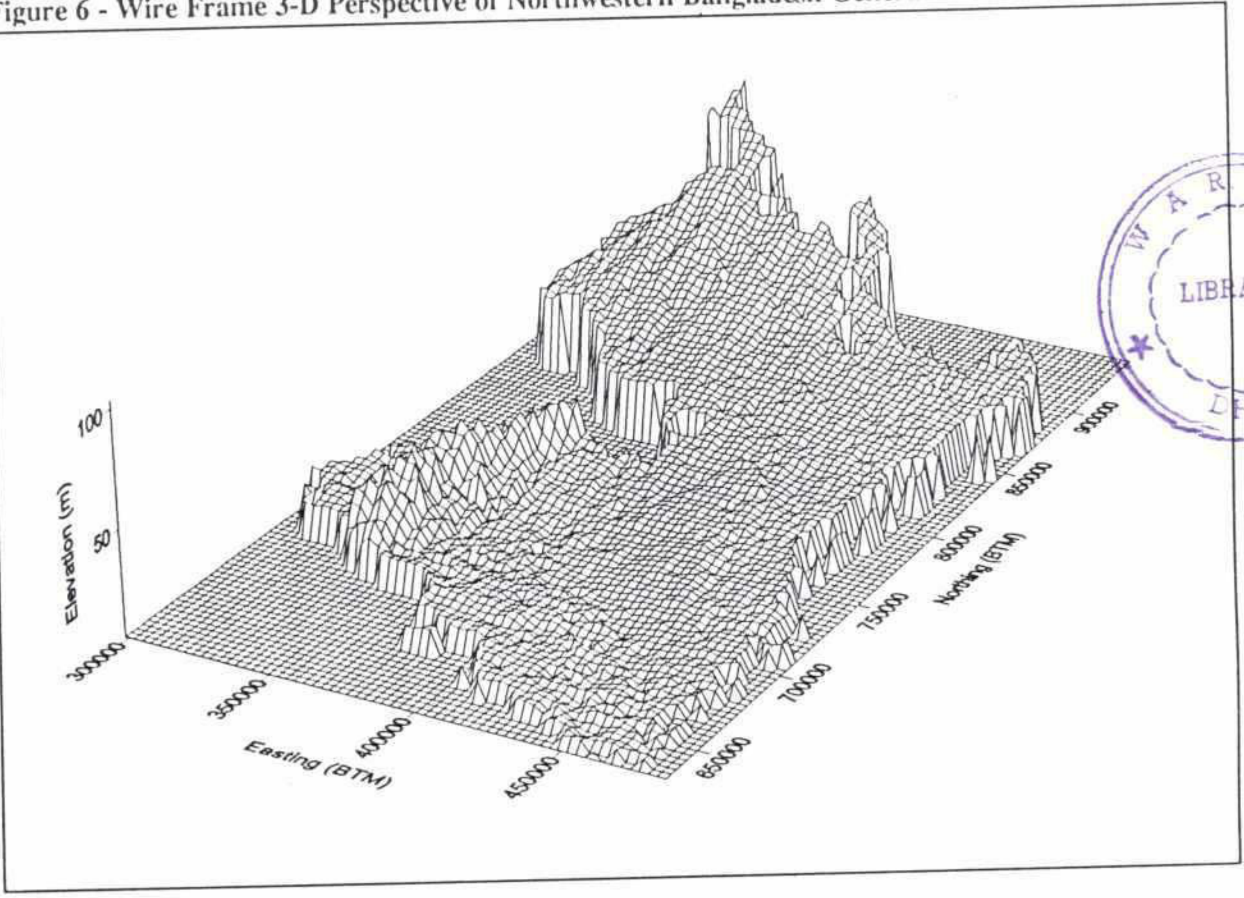


Figure 5 - Digital Elevation Model

Figure 6 - Wire Frame 3-D Perspective of Northwestern Bangladesh Generated From a DEM.



- Flood modeling and mapping, flood forecasting, and floodplain sedimentation modeling.
- Construction planning and cut/fill volume analysis for flood control structures, canals, and dams.
- Geomorphological studies.
- Soil erosion modeling.
- Crop suitability modeling.
- Landscape visibility analysis.
- Road/utility routing.
- Environmental impact assessment.
- Environmental modeling.
- Natural resource modeling.
- 3-D perspective views for showing before/after scenes simulating the effect of proposed development.

See Appendix-1 or the FAP 19 Technical Report "Medium Resolution Digital Elevation Model of Bangladesh" for further information on the DEM database and its applications.

3.6 Water Resource Monitoring

The BWDB manages a variety of water resource monitoring data sets that are readily amenable to GIS mapping and analysis. Among these are geo-referenced tabular data that describe the location of river water level and discharge gauging stations as well as rainfall monitoring stations for all of Bangladesh. These data, originally in tabular spreadsheet format, were converted by FAP 19 into spatially referenced ARC/INFO coverages (Figure 7).

The water level and discharge gauging stations were installed and are maintained by the Surface Water Hydrology II Division of the BWDB and Bangladesh Inland Waterways Transport Authority (BIWTA). Good quality water level and discharge data is critical for flood forecasting and warning, flood modeling, and water resource management and planning projects. Gauge attendants at each water level and discharge station collect data at various intervals based on the importance of the station. The Surface Water Modeling Center (SWMC) has enhanced the quality and frequency of data collection capability at some of the stations to facilitate their modeling activities.

The locations of these stations were digitized from a BWDB Hydrological Network map produced by Surface Water Hydrology-II. The different categories of monitoring stations defined in the coverage are listed below:

- Existing hydrological stations (water level and discharge; water level only).
- Selected existing hydrological stations (water level and discharge; water level only).
- Proposed hydrological stations (water level and discharge).
- Hydrology water level recorder.
- BIWTA water level stations.
- Selected water level stations where river discharge measurements can be requested.
- Hydrological stations (water level and discharge) equipped with a water level recorder.
- BWDB tidal stations.

These data were subsequently updated with station number, river name, and location by FAP 19.

In 1961, BWDB began installing rainfall stations throughout Bangladesh. The station locations were selected to allow even distribution throughout the country, proximity to rivers, and accessibility. The geographic locations, station names, district, type, platform elevations (m), installation date, data availability, daily rainfall measurements, and site descriptions were obtained from BWDB. FAP 19 added forecast and 30-year adjusted mean annual rainfall to the file and generated an ARC/INFO point coverage of national rainfall stations. The types and number of rainfall stations encoded in the coverage are given in Table 4. (See Appendix-1 for further information.)

3.6.1 GIS Mapping of BWDB Flood Forecasting Data

The Ganges, Brahmaputra, and Meghna rivers, which flow through Bangladesh, represent one of the most complex and flood-prone river delta systems in the world. The system carries a large volume of Himalayan snowmelt and drains the northeastern highlands of the Indian subcontinent. These factors, combined with heavy monsoon precipitation, often causes extensive flooding. In an attempt to better prepare Bangladesh with flood forecasting information, the BWDB operates a Flood Information Centre

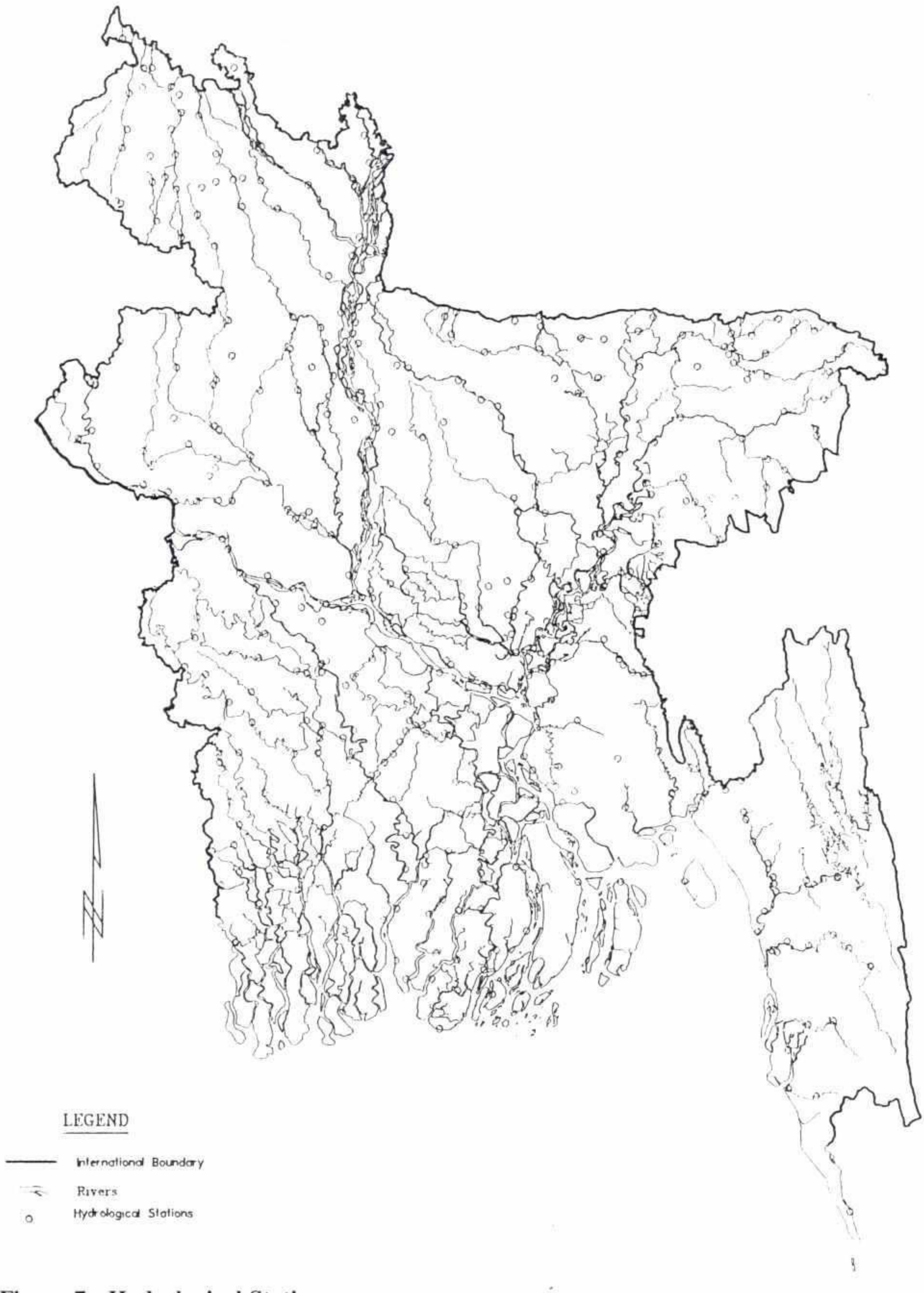


Figure 7 - Hydrological Stations

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Table 4 Types and Number of Rainfall Stations

Rainfall Station Categories:	Number of Stations
Manually operated rainfall stations	192
Auto rainfall stations	8
Manually operated rainfall and evaporation stations	11
Auto rainfall and evaporation stations	2
Forecasting rainfall stations with wireless	18
Forecasting auto rainfall stations with wireless	6
Forecasting rainfall and evaporation stations with wireless	13
Forecasting auto rainfall and evaporation stations with wireless	7
Forecasting auto rainfall and evaporation stations without wireless	1

that monitors water levels at 38 water level stations along the three major river basins. During monsoon season, the Flood Forecasting and Warning Division (FFWD) of the Centre also forecasts flood levels at 10 of those stations.

While the FFWD data and forecasts are reasonably accurate, extracting and visualizing information from the tables can be time-consuming for planners, policy makers, and disaster managers who need the information. FAP 19 developed a system that reproduces the information in a more easily interpreted map form. This type of mapping is intended to:

- Help planners immediately assess daily flood scenarios.
- Provide support information necessary for the improvement of flood management policy.
- Help disaster managers better anticipate and plan for floods.

The first step for mapping FFWD data and forecasts was to create a schematic representation of each of the major rivers showing the reaches covered by the 38 FFWD gauging stations. The boundaries of the 38 reaches were digitized manually as an overlay on a map of Bangladesh. Each reach in the digital map was then assigned an identification number that would allow it to be linked to relational database tables containing FFWD flood report data.

Flood "danger level" is defined as the level above which floods will likely damage crops and homesteads. Using this definition, FFWD established a standard danger level for each of its gauging stations. The difference between the daily water level and the danger level is the flood level. Two types of maps were produced: a flood level map and one based on the daily change in the water level. The map data for flood level were categorized as follows:

- Below danger level (greater than 10 cm below the BWDB danger level).
- At danger level (within plus or minus 10 cm of the BWDB danger level).
- 11-30 cm above BWDB danger level.
- 31-50 cm above BWDB danger level .
- Greater than 50 cm above BWDB danger level.

The map data for daily change in water levels were categorized as follows:

- Below danger level.
- At/above danger level and rising more than five cm from the previous day.
- At/above danger level and falling more than five cm from the previous day.
- At/above danger level and no change (rising or falling less than five cm from the previous day).

Spreadsheet analysis was used to calculate the flood level and the daily change in water level from the tabular FFWD flood report data. These data were then entered into a relational database table and linked to the digital river reach map. A series of maps were generated for flood forecast dates between 23 to 26 July, 1993, to test the results. One of these maps, shown in Figure 8, depicts river levels with respect to the BWDB danger level. Another map, shown in Figure 9, illustrates the rise and fall situations of the rivers relative to the previous day's water levels. These maps can easily depict potentially dangerous trends in flood levels on regional basis. Such data visualization tools could have wide applications for politicians as well as those involved in flood mitigation and response planning, and would be a useful compliment to the daily flood forecast report now produced by the FFWD. (See FAP 19 Technical Report - "GIS Mapping of BWDB Flood Forecasting Data", 1994.)

3.7 Demography

The [4]BBS 1991 national census data was linked to the FAP 19 National Database administrative boundary data layers (see Section 3.1). The thana level data themes derived from the census include total population, household, 7-years-old and older male and female literacy rates, and population of those age 18 and above. These data were manually entered into dBASE IV database tables and then related to thana coverage PATs. The 1981 thana-level census data on population density and household density was also collected from BBS as a digital database file and relationally joined to the National Database thana coverage. Thana areas from the BBS census data were used for computing densities.

Using the links between the thana polygons and the tabular census data, thematic maps based on the BBS demographic data can be generated using ARC/INFO (Figure 10). Further, these primary thematic maps can be integrated using GIS overlay analysis to produce new information. For example, a map of population density change per sq. km. between 1981 and 1991 was generated. The same technique can be used to create additional GIS maps from more detailed BBS census data, i.e., at the union or mouza level.

[4] Bangladesh Population Census, 1991, Vol.2, Union Statistics

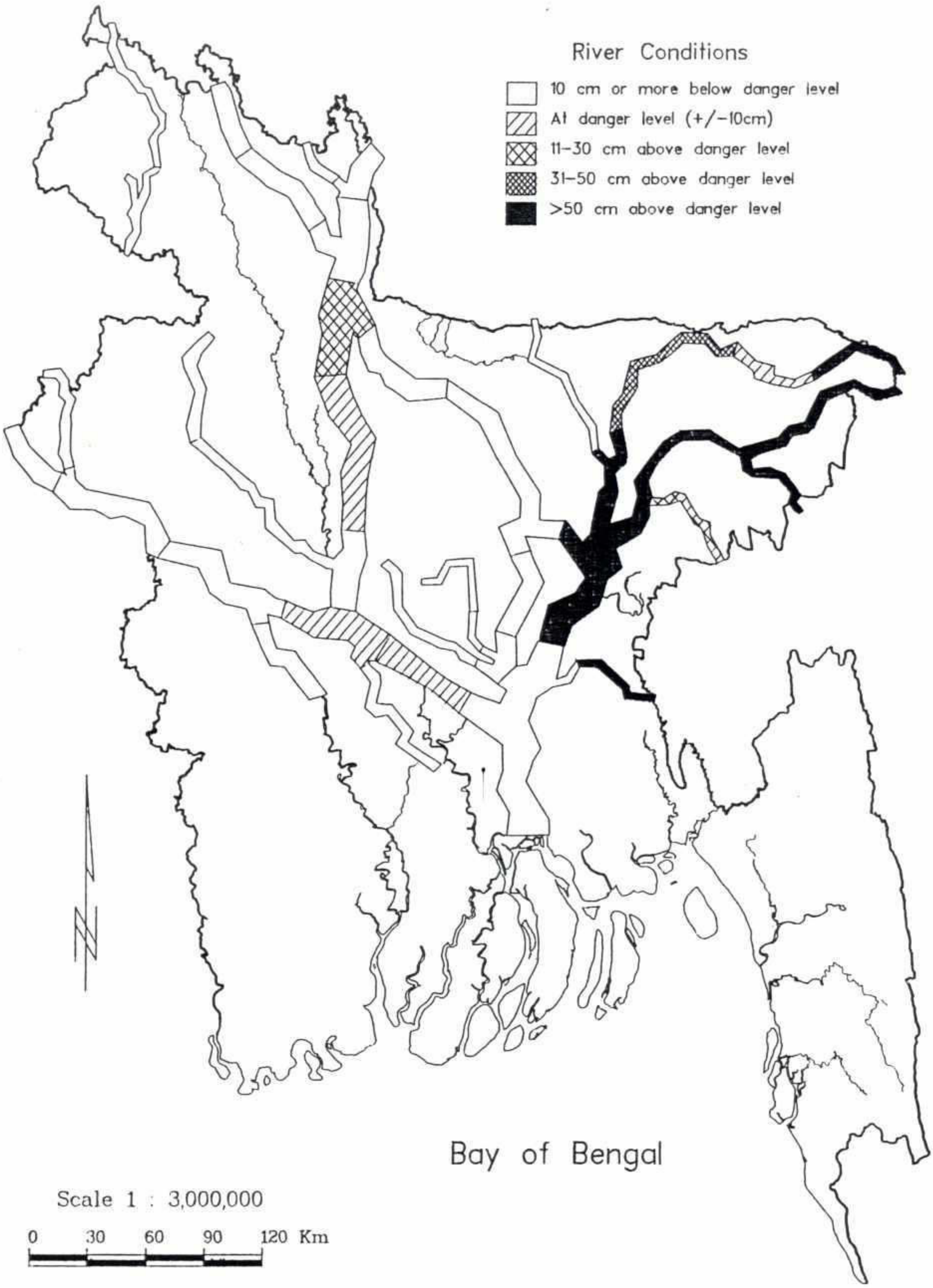


Figure 8 - Flood Warning Schematic of 24 July, 1993

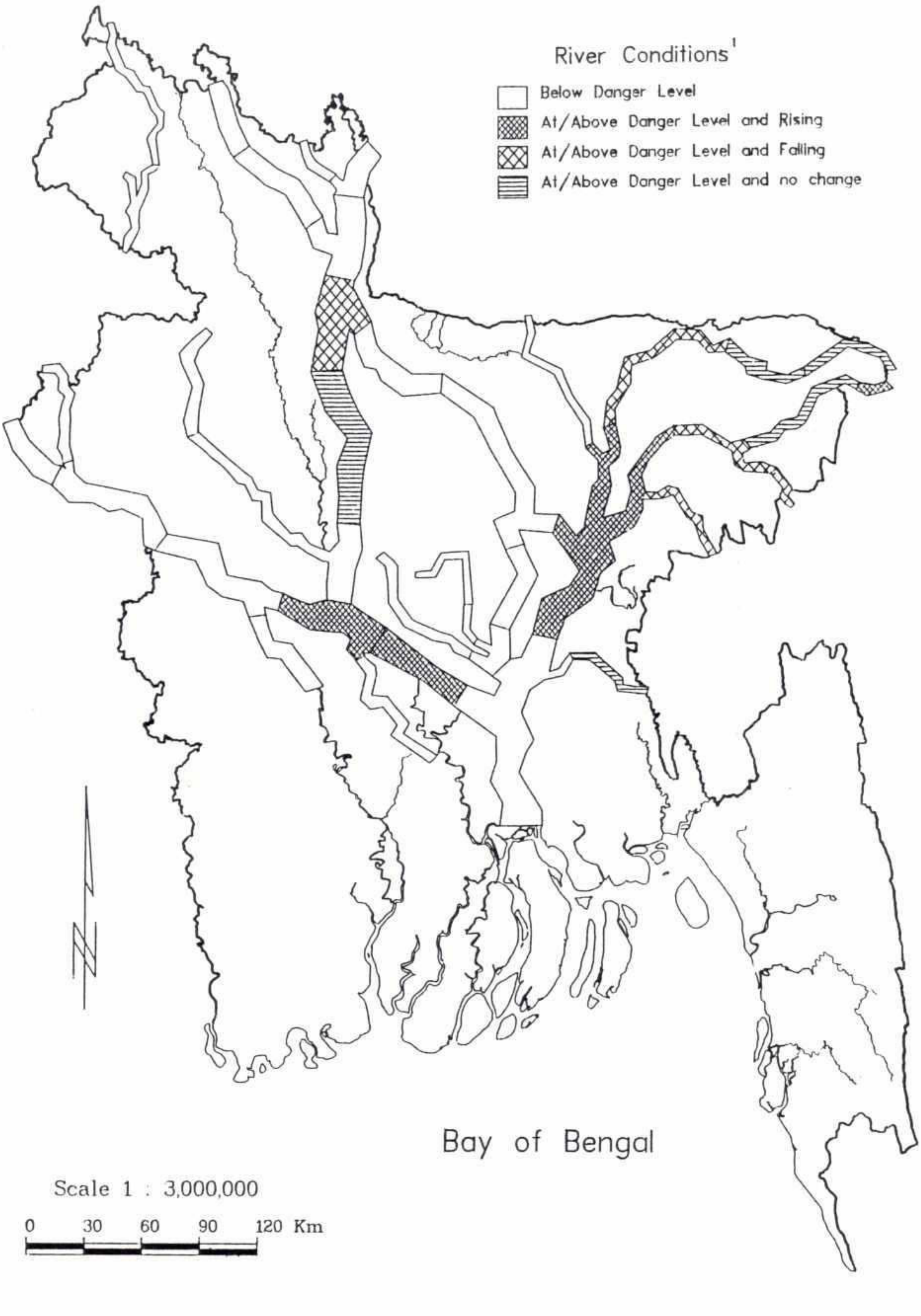


Figure 9 - Schematic of River Rise/Fall on 24 July, 1993

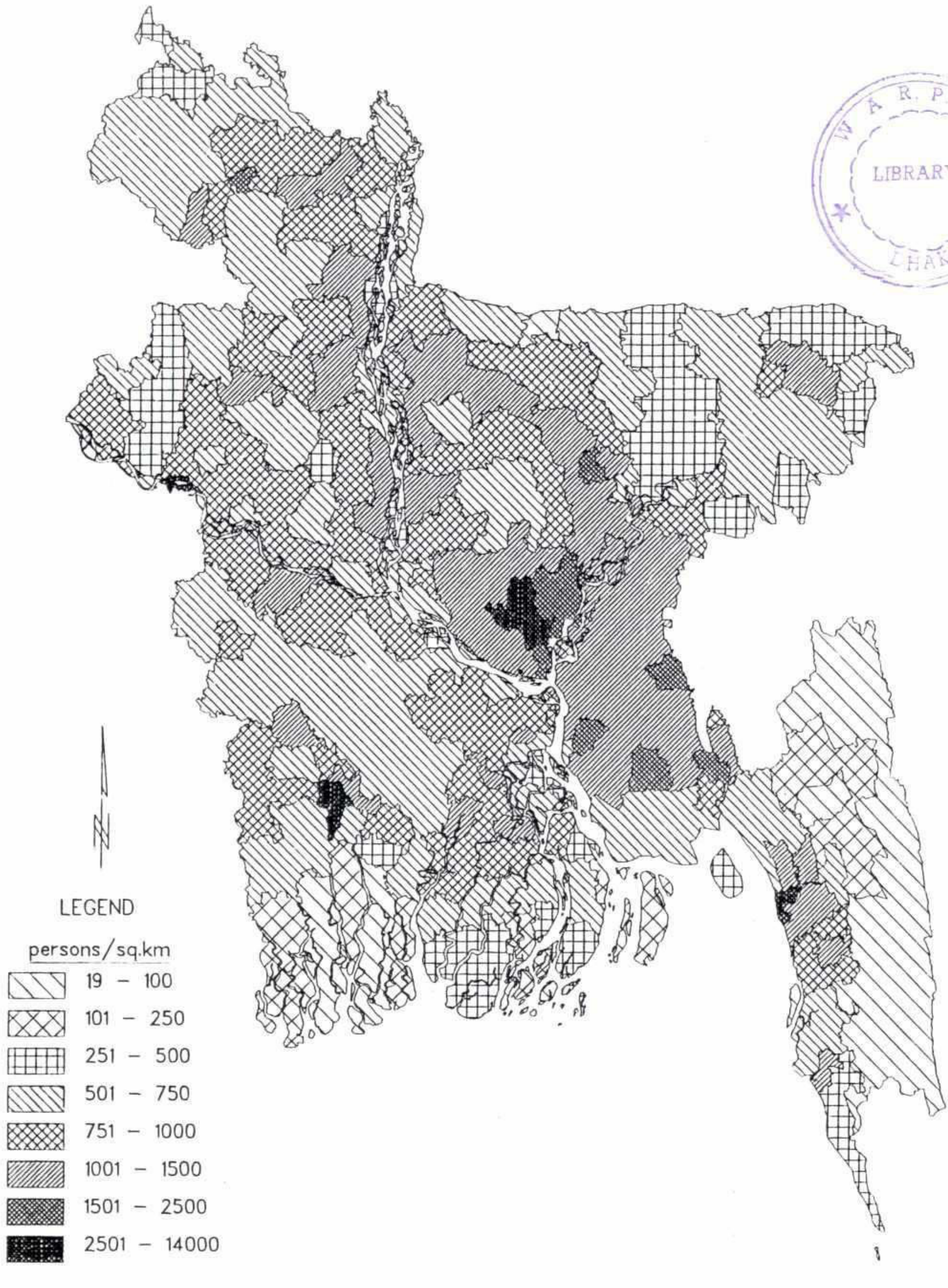


Figure 10 - 1991 Population Density

3.8 Flood Inundation Land Type (Flood Depth)

Geographic information systems have the ability to combine data themes using a variety of spatial analysis techniques to create new layers of spatial information. An example of one such derived data theme, flood-inundation land type, was created from two of the primary data sources described above (Sections 3.1-3.7). Flood inundation land type is a data theme resulting from a GIS analysis involving a DEM and digital soils data--effectively a digital map of "normal" flood depths during the monsoon season.

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. Planners also use flood depth maps for determining how land can be developed or improved by different development projects, and for predicting impacts of flood intervention projects.

The MPO developed the flood depth classification scheme shown in Text Box 1 (Master Plan Organization, 1987).

Text Box 1 - MPO Flood Depth Categories

FLOOD CATEGORY	FLOOD DEPTH
F_0 — Nonflood	0 - 0.3m
F_1 — Shallow Flood	0.3 - 0.9m
F_2 — Medium Flood	0.9 - 1.8m
F_3 — Deep Flood	1.8 - 3.6m
F_4 — Very Deep Flood	> 3.6m

Alternatively, the UNDP-FAO Land Resources Appraisal of Bangladesh for Agricultural Development classified inundation depth according to landscape position (land type) in their AEZ mapping. The soil attribute data linked to the soil association map units in the FAP 19 database uses the AEZ system. This system differs from the MPO scheme in that it classifies wetlands, not just inundation depth due to riverine flooding. There are a total of six inundation land types based on the normal flood level (Text Box 2).

Text Box 2 - AEZ Land Type Categories

AEZ LAND TYPE CATEGORY	FLOOD DEPTH
H — Highland	Land above the normal inundation level
MH1 — Medium Highland 1	0 - 0.3m
MH2 — Medium Highland 2	0.3 - 0.9m
ML — Medium Lowland	0.9 - 1.8m
L — Lowland	1.8 - 3.0m
VL — Very Lowland	> 3.0m

For the purposes of this analysis, the MPO system was deemed more appropriate. Because the FAP 19 soils database uses the AEZ system, however, it was necessary to determine equivalent categories as shown in Text Box 3.

Text Box 3 - Equivalent MPO ↔ AEZ Categories

MPO CATEGORY		AEZ CATEGORY
F_0 — Non-flood	↔	H, MH1
F_1 — Shallow Flood	↔	MH2
F_2 — Medium Flood	↔	ML
F_3 — Deep Flood	↔	L
F_4 — Very Deep Flood	↔	VL

As discussed in Section 3.4, a *soil association* is a particular pattern of soil bodies that is made up of a number of *soil series* characterized by similar parent material and environmental conditions. These are, in turn, further subdivided into *soil phases* based on land use considerations. In Bangladesh, the most common soil phase is the depth of flooding inundation classes: highland, medium highland, lowland. Flood inundation interpretations for each soil phase were made by SRDI during their Soil Reconnaissance Survey. Due to the complexities of the soil associations, it was not possible to map the actual flood inundation boundaries at the reconnaissance mapping scale; thus, the data describes the quantity, but not the location, of each flood depth class. This poses an obvious impediment to map production.

Fortunately, the FAP 19 GIS provided the tools and the National Database the data for deriving flood depth maps. Producing inundation land type maps requires using the soils and topography data layers from the FAP 19 database. Figure 11 is a process diagram that illustrates the land type mapping procedure. The figure also includes a description of the general algorithm on a per polygon basis, i.e., the algorithm is performed sequentially on each soil polygon in the input soil map.

Thus, a percentage of the area in each soil association polygon is allocated to a flood depth category based on the land type proportions in the ARC/INFO polygon attribute table. For example, if 15 percent of a soil association belonged to the F_0 class (highland), then the highest-elevated 15 percent of the polygon area would be assigned to that class using the DEM. The remaining area in the polygon is subsequently allocated to each of the flood depth classes lower in the landscape in the same manner using the DEM. The elevation ranges needed to assign DEM pixels to flood classes are obtained by constructing an area-elevation curve: a function for cumulative percent area vs. pixel elevation (Figure 11). This curve is used to determine the elevation "breakpoints" that define flood class ranges.

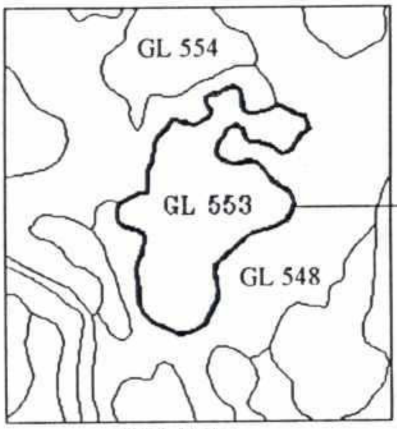
The land type algorithm was implemented with several ERDAS programs and dBASE IV application programs. The dBASE programs are accessed via a "toolbox" of software utilities created by FAP 19. The FAP 19 National Database Toolbox contains application specific functions for acquisition, manipulation, and analysis of FAP 19 data sets. The program includes a module created specifically for land type mapping.

Regional land type maps were developed in raster format. The regional maps were then merged into a single, national land type map that was converted to vector format to extend its utility. The regional maps were prepared in ERDAS format, the national level map was prepared in ERDAS (Figure 12) and ARC/INFO. (See Appendix 1 for more information.)

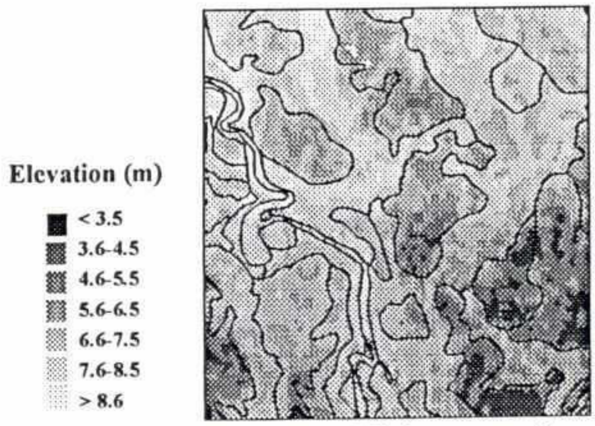
LAND TYPE MAPPING

Polygon Attribute Table

AEZ Code (Soil Assoc.)	Land Type Distribution (%)				
	FO	F1	F2	F3	F4
GL 548	55	35	10	0	0
GL 553	31	44	20	5	0
GL 554	17	28	45	10	0

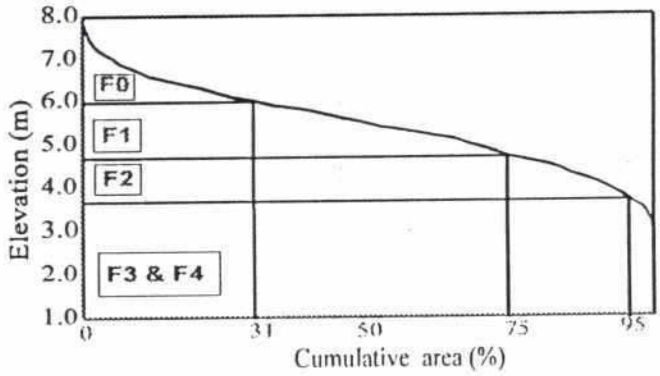


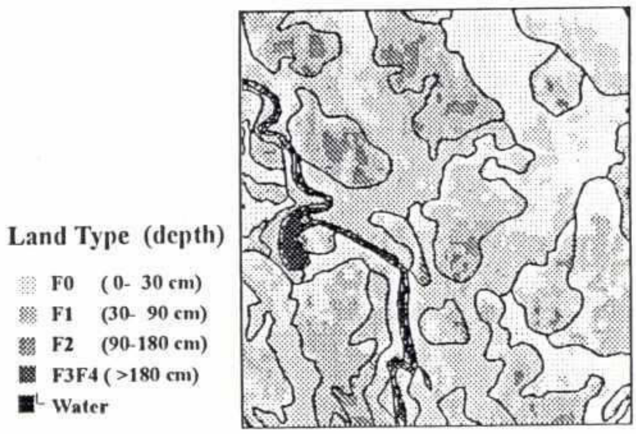
SOIL MAP



DEM

Area Elevation Curve





LAND TYPE

Algorithm for Delineating Land Type Map

1. Obtain the percentage of each land type (F_0 - F_4) in the soil association polygon from the ARC/INFO Polygon Attribute Table (PAT).
2. Locate the DEM pixels which geographically correspond to the same polygon via GIS overlay techniques.
3. Sort the DEM pixels by elevation in descending order.
4. Allocate the sorted pixels (high - low) to land type classes (F_0 - F_4) based on the percentages obtained in step 1, i.e., the highest pixels are allocated to highland areas (F_0) using the appropriate percentage, and so on down to lowland (F_4) which is allotted the lowest elevation pixels.
5. Repeat steps 1-4 until all soil association polygons on the map are classified.

Figure 11 - Procedure for Deriving Land Type (Flood Depth) Maps

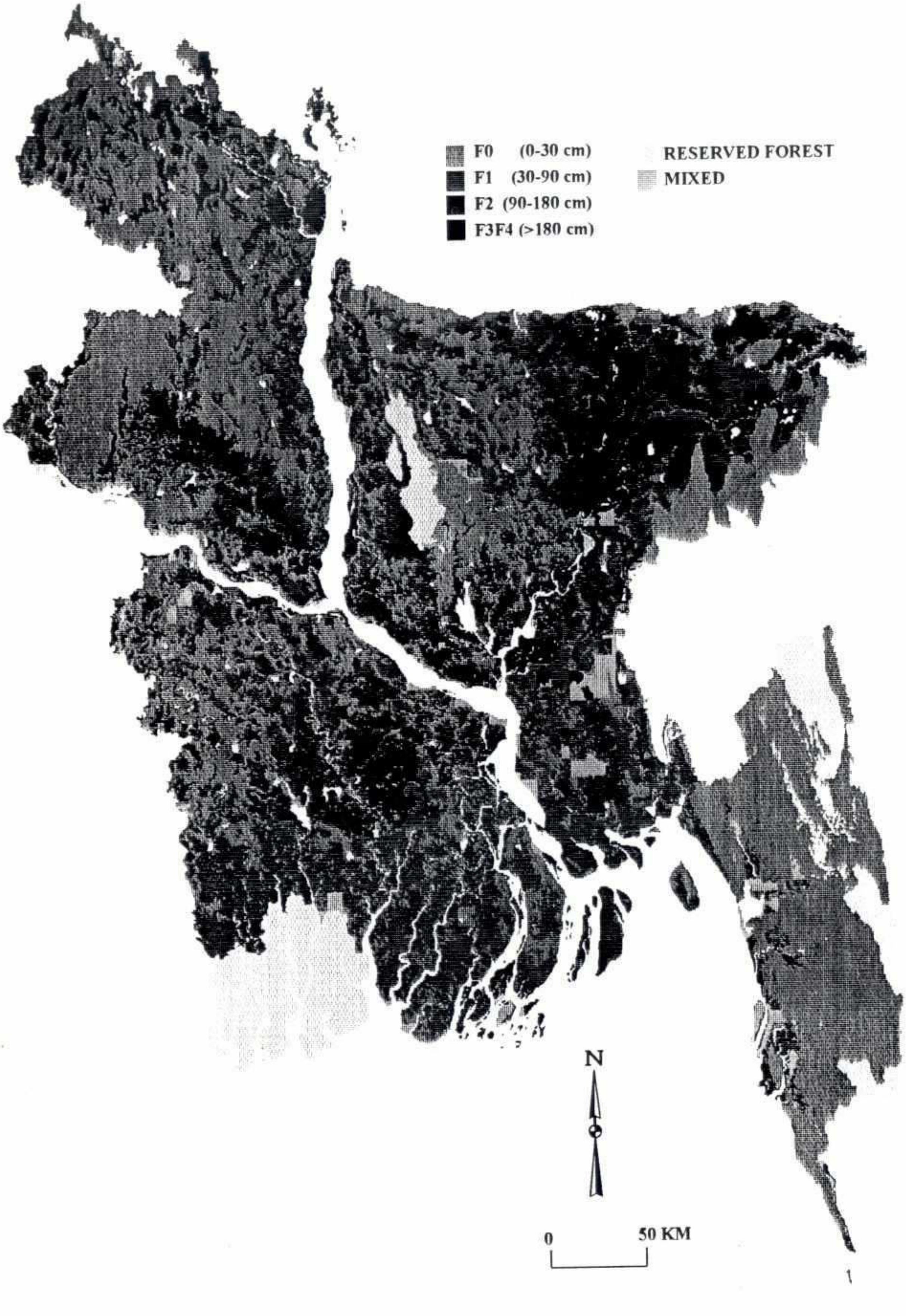


Figure 12 - Inundation Land Type: "Normal" Monsoon Flooding

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4. Regional and Local Accessory Data and Pilot Studies

A number of specialized databases, generated by FAP 19 through application projects and pilot studies, were incorporated into the National Database. These data sets are limited either to a particular geographic or physiographic region in Bangladesh, or by the fact that the data is unevenly distributed throughout the country. Despite constraints, these GIS data sets are valuable to environmental and socioeconomic applications in Bangladesh because of their geographic domain or specialized data content. The data specifications and lineage of these data sets are not defined in Section 5 of this report. Instead, the reader is referred to the list of FAP 19 publications in Appendix 6.

4.1 Ground Water

Thana level thematic information on groundwater with corresponding geographic coordinates was provided to FAP 19 in worksheet file format from the MPO. The hydrologic attributes included in this file were: percent of land irrigable from ground water, usable recharge (mm), and percent of land actually irrigated from groundwater at 80 percent efficiency.

Initially an ARC/INFO point coverage was generated using the geographic point coordinates contained in the spreadsheet. Thana names and district names were added to the PAT and related to the corresponding FAP 19 National Database coverages. The point files were converted to ERDAS format and transformed to raster surface maps via spatial interpolation (Figure 13). Although useful for visualizing gross geographic distribution of these data, the uneven (clustered) distribution of the original data points limits the validity of this data set on a national level.

4.2 Household Expenditure

In addition to the national level census, field data collected by the BBS in their Household Expenditure Survey was used by FAP 19 to perform a pilot study of GIS potential using these BBS data. The data provided by BBS were in the form of a dBASE IV database file containing the survey data from their 360 primary survey units distributed throughout the country. One primary survey unit consists of approximately 15-16 households. There are 20 attributes in the database file, a unique record identifier, administrative unit, and corresponding geographic coordinates allowing each attribute to be mapped and visualized. The main attributes used in the pilot study were per capita calorie intake, education expenses, and health expenses for male and female.

In order to effectively visualize the data, the point values were transformed to a surface. This was possible despite the fact that the data points were not evenly distributed throughout Bangladesh. To accomplish this, an ARC/INFO point coverage was generated from the 360 primary survey unit data points and a surface map was produced by spatial interpolation using ERDAS programs. Five thematic maps were prepared: calorie intake per capita (Figure 14), medical expenses for male and female, and health expenses for male and female. This pilot study found such data useful for visualizing gross geographic distribution of these socioeconomic data.

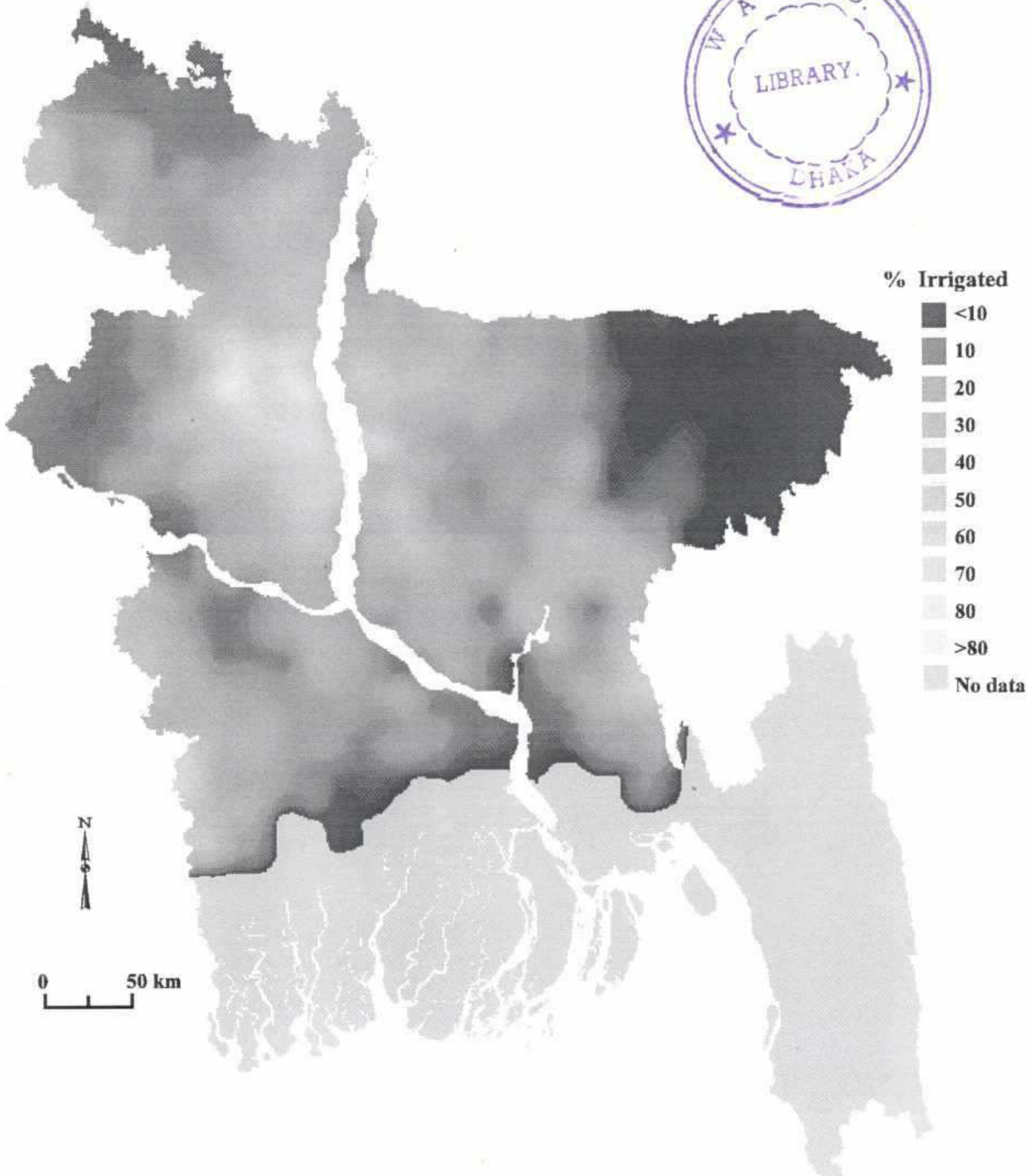

Figure 13 - Example of Raster Surface: Land Irrigated From Ground Water, 1991

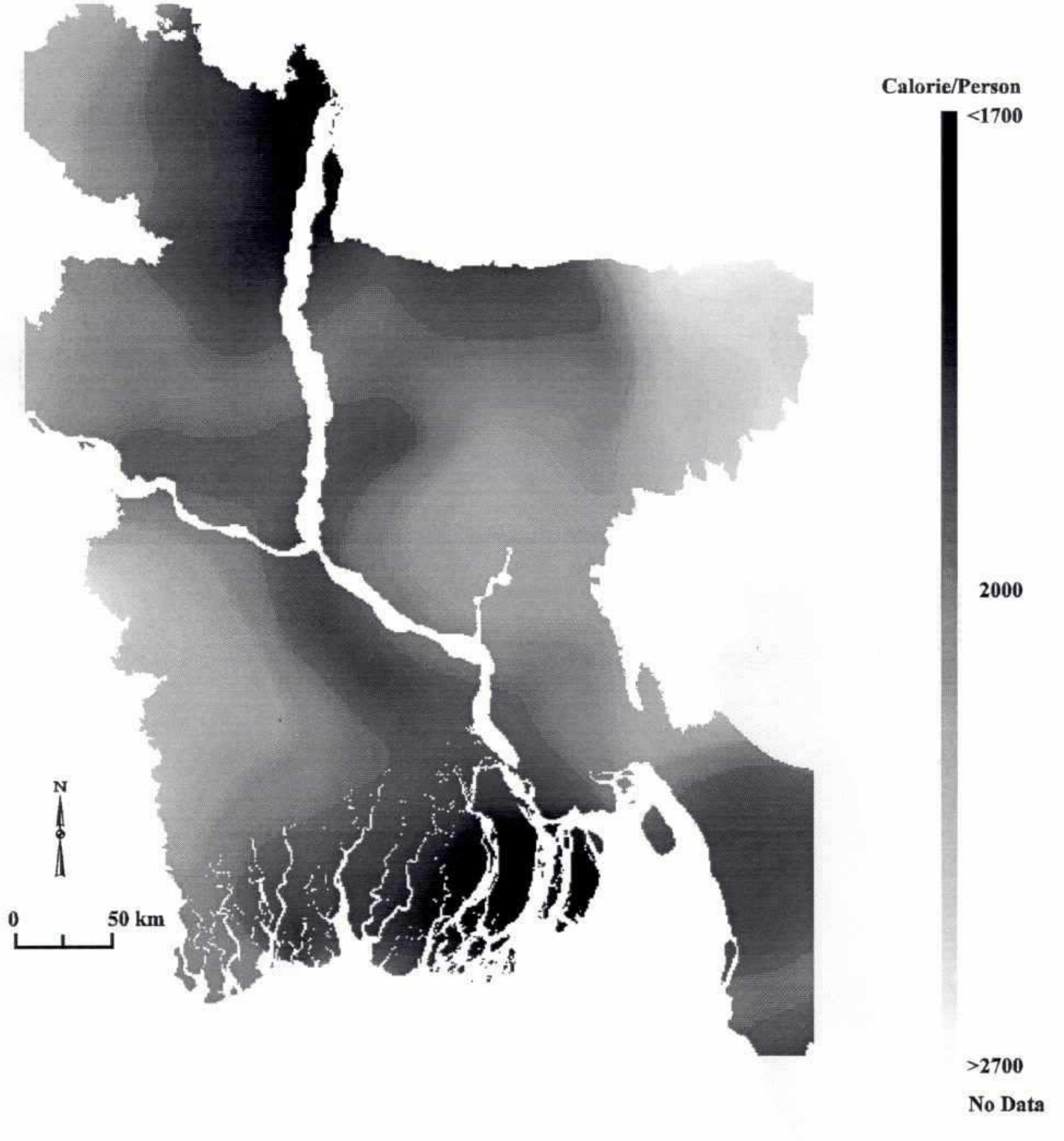

Figure 14 - Per Capita Calorie Intake

4.3 Tangail CPP Data Sets

A number of FAP 19 studies were done in collaboration with the FAP 20 Compartmentalization Pilot Project (CPP) in Tangail. In these projects, FAP 19 provided the CPP with improved base maps, specialized flood scenario maps (e.g., flood depth under various scenarios), and analysis of variation of features within the CPP (e.g., population density).

Base maps were improved by examining and interpreting SPOT satellite images to locate features such as roads and embankments, and FAP 20 information about sluices and culverts was added to the GIS database. All these features were subsequently digitized and base maps were plotted.

FAP 19 produced the FAP 20 flood depth map for the Tangail compartment by first creating a DEM using spot heights digitized from 8 in./mile BWDB maps. All elevations in the 175 m x 175 m network of spot heights were digitized and processed to create DEMs using methods similar to that described in Section 3.5 of this report. The project also used the software MIKE 11, a hydrodynamic model developed by the Danish Hydraulic Institute. Using the MIKE 11 flood modeling results, FAP 20 provided water levels for each sub-compartment under various water management scenarios. These data were used by FAP 19 to create a digital water level surface. The water and land elevation surfaces were intersected to produce flood depth maps for assessing water management alternatives and to assist in verifying FAP 20's flood model.

The Environmental Study (FAP 16) also selected the Tangail CPP study area for an environmental impact assessment case study. The FAP 19 GIS was used in this study as a mapping and analytical tool. Analysis focused on the use of inundation land type (flood depth) maps for formulating different planning scenarios and the assessment of associated environmental impacts. A full description of the map themes and associated statistics were compiled by FAP 19 in the Tangail Area GIS Atlas (FAP 19 Technical Note No. 4). (See the following FAP 19 publications for further information: "Classification of Flood Depth and Extent Using MIKE 11 and GIS", 1993; Technical Notes No. 4 and 6.)

4.4 Charlands Inventory

Residents of island *chars* and the mainland adjacent to the major rivers of Bangladesh live in one of the most hazard prone environments in Bangladesh. Most of these people are located outside the areas protected by structural flood protection works, hence, embankments may even increase the flood and erosion risks to which they are exposed by raising flood levels. FAP 19, in collaboration with FAP 16, studied the resources and people of the charlands of the Brahmaputra-Jamuna, Ganges, Meghna, and Padma rivers. Objectives of the study included:

- Creating a GIS database that includes thematic maps created using tabular data from a FAP 16 inventory of the resources, people, and infrastructures in the Brahmaputra-Jamuna, Ganges, Meghna, and Padma charlands.
- Using digital satellite images to analyze physical changes and land use in these areas, and integrating this analysis with inventory data using a GIS.

The charland socioeconomic data collected by FAP 16 included an inventory of population, migration, health and education services, infrastructure, crops, resource availability, and flood hazards. For each river in the study, FAP 19 digitized *mauza* boundaries for the charlands and adjacent mainland from

Bangladesh Police Station maps. Inventory data was entered in to dBASE IV tables and linked to the GIS *mauza* database. Numerous *mauza*-based GIS maps were produced for each socioeconomic data theme. These maps offer a means to visually and quantitatively interpret these socioeconomic data for planning and policy development in the charlands.

In addition to inventory data presentation and analysis, a time series of LANDSAT satellite images were georeferenced and classified according to land cover and used for quantification of historic morphological changes in the major rivers. Eight images during the period 1973-1992 were used for the Jamuna, and two images, 1984 and 1993, were used for the Ganges, Meghna, and Padma. The banklines of the rivers were digitized on-screen by displaying the image with ERDAS and tracing the banks with a "mouse" using ARC/INFO programs. Maps and tables illustrated changes in river morphology, such as erosion/accretion, movement of river center lines, and changes in channel width. Using GIS analysis, the land cover map was also overlaid with the *mauza* boundaries to assess the affects of floods and river erosion on those residing in the area.

The *mauza* and bankline data exist as ARC/INFO polygon and line coverages, respectively, and the images are archived in ERDAS image formats. (See the following series of FAP 16/19 publications for further information: "The Dynamic Physical and Socioeconomic Environment of Riverain Charlands", 1993.)

5. Considerations For The Future

The FAP 19 National Database project has gathered spatial data in an integrated GIS format. There are limitations in the use of the data due in part to the resolution of the source maps and to the quality of the source attribute data. The database should be considered an on-going effort and improvements or additions to the database are encouraged. It is essential that users of the database are engaged in its improvement; edits and updates should be reincorporated into the database and made available to other users.

This database is the first effort to establish comprehensive digital coverages of Bangladesh. No doubt, new data will become available that will replace the FAP 19 data. For example, LGED compiled a series of thana base maps at 1:50,000 scale covering all of Bangladesh. Included in the base maps are administrative boundaries and infrastructure features. LGED is now constructing digital databases from the maps which are scheduled for completion before the end of 1995. Some of the information, such as roads and railways, will be more complete and detailed than the equivalent data layers in the FAP 19 National Database. Once these data sets are complete, they will supersede the current FAP 19 data layers and will hopefully be accessible to users of the FAP 19 National Database.

LIST OF REFERENCES

The following is a list of FAP 19 reports produced as of May 30, 1995.

Reports:

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

Technical Reports:

Comparison of Elevation Data from BWDB and FINNMAP (Jan 93)
Classification of Flood Depth and Extent Using Mike 11 and GIS (Feb 93)
GIS Technology for Disaster Management Pilot Study Interim Report (Oct 93)
GIS Mapping of BWDB Flood Forecasting Data (Apr 94)
Satellite Radar Applications for Water Resources in Bangladesh (in preparation)
Medium Resolution Digital Elevation Model of Bangladesh (May 95)
Bangladesh National Level GIS Database (May 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 (March 95)

Training Manual:

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

Archive Documents:

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

Reports in Collaboration 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)

APPENDICES

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APPENDIX 1: DATA SPECIFICATIONS AND LINEAGE

A1.1 Administrative Boundaries

A1.1.1 Thana

Title of the Coverage/File: **UPAZILA** (Figure 1)

Date Completed/Revised: December 1994 (revised)

File Format: ARC/INFO Polygon/Line coverage

Projection: Bangladesh Transverse Mercator

Source: Agroecological zone (AEZ), UNDP-FAO, 1985; 1:250,000 scale

Digitizing Methods: The data were digitized from the 17 UNDP-FAO AEZ zone maps by AST using TYDAC SPANS. FAP 19 produced software using a PASCAL compiler to convert these data into ARC/INFO GENERATE format (ASCII) and subsequently create coverages. The coverages were transformed to BTM coordinate system using SOB maps for ground control. All coverages were combined using the ARC/INFO APPEND command and then edge matched by manually editing with ARCEDIT.

Data Processing: To standardize the thana coverage, FAP 19 checked boundary alignments and the total number of thanas with BBS administrative units maps. In some cases, the thana boundaries did not match the BBS maps, and the total number of thanas varied from BBS data-sheets (Bangladesh Population Census, 1991, Vol.2, Union Statistics, BBS). Boundary mismatches were marked on photocopied maps for checking and recording purposes only. FAP 19 did not update the boundaries because the BBS maps were not accurate enough for digitizing.

Feature Codes: The user_id codes in the coverage AAT are as follows:
- Thana Boundary: 1
- District Boundary: 7
- International Boundary: 99
- Coast line/Islands/Coastal *Chars* : 9

Cautionary Notes:
- Edge matching problems occurred along the boundaries of the thana coverages.
- The original AST data identified Tongi a thana, but according to the BBS map Tongi is a municipality area of Gazipur Sadar Thana. Similarly, Dighalia thana in Khulna district appears on the BBS map, but is missing in the PAT file of the thana coverage.
- For data entry of various BBS statistics, the population of the municipal areas of the three metropolitan cities of Dhaka, Chittagong and Khulna had to be aggregated. These cities are treated as thanas.

FAP 19 Archive Index: Tape serial no. T-19

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A1.1.2 Thana Headquarters

Title of the Coverage/File: URBAN (Figure 1)

Date Completed/Revised: March 1995 (revised)

File Format: ARC/INFO Polygon coverage

Projection: Bangladesh Transverse Mercator

Source: Agroecological zone (AEZ), UNDP-FAO, 1985; 1:250,000 scale

Digitizing Methods: The data were digitized from the 17 UNDP-FAO AEZ zone maps by AST using TYDAC SPANS. FAP 19 produced software using a PASCAL compiler to convert these data into ARC/INFO GENERATE format (ASCII) and subsequently create coverages. The coverages were transformed to BTM coordinate system using SOB maps for ground control. All coverages were combined using the ARC/INFO APPEND command and then edge matched by manually editing with ARCEDIT.

FAP 19 Archive Index: Tape serial no. T-1

A1.1.3 Districts

Title of the Coverage/File: DISTRICT

Date Completed/Revised: August 1994 (revised)

File Format: ARC/INFO Polygon/Line coverage

Projection: Bangladesh Transverse Mercator

Source: Agroecological zone (AEZ), UNDP-FAO, 1988; 1:250,000 scale

Digitizing Methods: The data were digitized from the 17 UNDP-FAO AEZ zone maps by AST using TYDAC SPANS. FAP 19 produced software (PASCAL language) to convert these data into ARC/INFO GENERATE format (ASCII) and subsequently create coverages. The coverages were transformed to BTM coordinate system using SOB maps for ground control. All coverages were combined using the ARC/INFO APPEND command and then edge matched by manually editing with ARCEDIT.

Data Processing: To standardize the district coverage, FAP 19 checked boundary alignments and the total number of districts with BBS administrative units maps. In some cases, the district boundaries did not match the BBS maps, and the total number of districts varied from BBS data-sheets (Bangladesh Population Census, 1991, Vol.2, Union Statistics, BBS). Boundary mismatches were marked on photocopied maps for checking and recording purposes only. FAP 19 did not update the boundaries because the BBS maps were not accurate enough for digitizing.

Feature Codes:
The user_id codes in the coverage AAT are as follows:

- Thana Boundary: 1
- District Boundary: 7
- International Boundary: 99
- Coast line/Islands/Coastal *Chars*: 9.

A list of the attribute fields included in the coverage PAT are as follows:

- GEOCODE: Geo-code of districts
- DISTNAME: District name
- CALORIE: Per capita calorie intake of 1991
- CALCODE: Calorie intake code for 1991
- Population Density Attributes: See section AI.7.1.

Cautionary Notes: Edge matching problems occurred along the boundaries of the district coverage.

FAP 19 Archive Index: Tape serial no. T-19

A1.1.4 National Boundary

Title of the Coverage/File: **INTBNDTM**

Date Completed/Revised: February 1995

File Format: ARC/INFO line coverage

Projection: Bangladesh Transverse Mercator

Source: SOB maps; 1:50,000 scale

Digitizing Methods: The boundary was manually digitized directly from SOB maps. ARC/INFO SMLs were used to expedite tic coordinate conversion from the Grid IIB (yards) projection to BTM. Of the 95 SOB maps sheets digitized, two (79M/15 and 83D/1) created digitizing problems. On 79M/15 and 83D/1, the Grid IIB (yards) coordinates were not accurately marked, but the problem was solved by re-digitizing the sheets with geographic coordinate (degrees) tics from the same SOB sheets. The 94 separate coverages were appended using ARC/INFO APPEND command. This appended coverage was projected into BTM after editing.

Feature Codes: The user_id codes in the coverage AAT are as follows:

- International boundary: 9

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A1.2 Infrastructure

A1.2.1 Roads

Title of the Coverage/File: ROADS (Figure 2)

Date Completed/Revised: August 1992

File Format: ARC/INFO Line coverage

Projection: Bangladesh Transverse Mercator

Source: Agroecological zone (AEZ), UNDP-FAO, 1988; 1:250,000 scale

Digitizing Methods: The data were digitized from the 17 UNDP-FAO AEZ zone maps by AST using TYDAC SPANS. FAP 19 produced software (PASCAL language) to convert these data into ARC/INFO GENERATE format (ASCII) and subsequently create coverages. The coverages were transformed to BTM coordinate system using SOB maps for ground control. All coverages were combined using the ARC/INFO APPEND command and then edge matched by manually editing with ARCEDIT.

Feature Codes: The coverage includes national highways, regional highways, and feeder roads, but they are not encoded as such.

Cautionary Notes: Edge matching problems occurred along AEZ coverage boundaries from road discontinuities caused by the fact that minor roads were not digitized.

FAP 19 Archive Index: Tape serial no. T-1

A1.2.2 Railways

Title of the coverage/file: RAILS (Figure 2)

Date Completed/Revised: August 1992

File Format: ARC/INFO line coverage.

Projection: Bangladesh Transverse Mercator

Source: Agroecological zone (AEZ), UNDP-FAO, 1988; 1:250,000 scale

Digitizing Methods: The data were digitized from the 17 UNDP-FAO AEZ zone maps by AST using TYDAC SPANS. FAP 19 produced software (PASCAL language) to convert these data into ARC/INFO GENERATE format (ASCII) and subsequently create coverages. The coverages were transformed to BTM coordinate system using SOB maps for ground control. All coverages were combined using the ARC/INFO APPEND command and then edge matched by manually editing with ARCEDIT.

Cautionary Notes: Edge matching problems occurred along the boundaries of the railway coverages.

FAP 19 Archive Index: Tape serial no. T-1

A1.3 Hydrography

Title of the coverage/file: (Figure 3)
RIVERS: All rivers and khals greater than or equal to 50 m in width, river *chars*, coastal *chars*, *beels*.
RIV_POLY: Rivers greater than or equal to 100 m width, land mass, river *chars*, coastal *chars*, *beels*
RIV_LINE: Rivers less than or equal to 100 m in width
RIVERS.GIS: All rivers, land masses, river *chars*, coastal *chars*, *beels*

Date Completed/Revised: October 1994

File Format:
RIVERS: ARC/INFO Line coverage
RIV_POLY: ARC/INFO Polygon coverage
RIV_LINE: ARC/INFO Line coverage
RIVERS.GIS: ERDAS 8-bit GIS file

Projection: Bangladesh Transverse Mercator

Source: SPOT Image maps, February 1989; 1:50,000.

Digitizing Methods: The data was digitized by FAP 19 from satellite image maps which were based on multispectral SPOT data acquired in February 1989 at 1:50,000 scale with a ground resolution of 20 m. SOB topographic maps at (1:50,000 scale) were used as a reference in image interpretation. BWDB maps at 1:7920 and 1:15840 scale also were used for image interpretation. Hydrographic features were digitized as line (narrow rivers) and polygon features (wide rivers, *beels*, *chars*, land masses) in ARC/INFO format.

Data Processing: The river network database exists as the four separate digital products listed above. The primary product the line coverage named RIVERS which includes all rivers, *chars*, and *beels*. RIV_POLY and RIV_LINE are accessory coverages which include only the polygon and line coverage features, respectively. In addition, a raster version of the river network was produced by converting the ARC/INFO vector products to an ERDAS 8-bit raster file using the ARC/INFO POLYGRID and LINEGRID commands, and the ERDAS ERDARC program. River names also were added from BWDB project maps. Annotations were repositioned and edited, and river names were entered into the AAT. See FAP 19 Technical Note 9 for further information.

Feature Codes: The user_id codes in for the coverage AAT's and PAT's are listed in Table 5 below. River name annotation is stored in the NAME1 field of the AAT. If a river had more than one name on the source maps, they were stored in the NAME2-NAME5.

Table 5 Attribute Codes for the River Coverages

River Width/Feature	AAT User ID	PAT User ID
<1 mm	1	—
1-2 mm	2	—
>2 mm	3 (bank line)	1 (water)
Land Mass	3 (bank line)	3 (land)
Beel (dry season)	4	4
Canal	6	—
Char	30	2

Cautionary Notes:

- Rivers/khals less than 50 m in width were not digitized.
- Some river courses could not be traced to their destination as they were not discernible on the maps.
- River bank lines (polygon features) were taken at confined channels, i.e., attached *chars* were placed within the river channel since they are normally submerged during the wet season. The actual river width at a particular location and time may vary considerably.
- Only large, well-defined water beels were included in the database.
- The dry season extent of beels was digitized.
- Tributaries and distributaries less than 5 cm in length on the SPOT image maps were not included.
- Island *chars* with areas less than 100 ha were not digitized.
- Maritime islands with areas of less than 500 ha were not digitized.
- The Chittagong area was not included in the database because it fell outside the FAP study region.

Map Accuracy: The rivers coverages and files were digitized from 1:50,000 scale maps for national and regional use.

FAP 19 Archive Index: Tape serial no. T-18

A1.4 Soils

Title of the coverage/file:
SOLALLCN: National Coverage
SOILNWR: Northwest regional coverage
SOILNER: Northeast regional coverage
SOILSWR: Southwest regional coverage
SOILSER: Southeast regional coverage
SOILNCR: North Central regional coverage

Date completed/revised: October 1994

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File Format: ARC/INFO polygon coverage.

Projection: Bangladesh Transverse Mercator

Source: Agroecological zone (AEZ), UNDP-FAO, 1988; 1:250,000 scale

Digitizing Methods: The data were digitized from the 17 UNDP-FAO AEZ zone maps by AST using TYDAC SPANS. FAP 19 produced software (PASCAL language) to convert these data into ARC/INFO GENERATE format (ASCII) and subsequently create coverages. The coverages were transformed to BTM coordinate system using SOB maps for ground control. All coverages were combined using the ARC/INFO APPEND command and then edge matched by manually editing with ARCEDIT.

Data Processing: Modifications were made to the soil coverages to include soil attribute fields in the PAT from the AEZ database. These fields contain the dominant class of the corresponding soil property for each AEZ soil association map unit. To determine the dominant series or phase level, a program called The FAP 19 National Database Toolbox was developed. The program calculates the percentage of area occupied by each class of a given soil property and inserts the dominant class in the corresponding field of the PAT. A description of the soil properties and the algorithm for selecting dominance can be found in Appendix-7, and procedures for using the FAP 19 National Database Toolbox are given in Appendix 6.

Feature Codes: The coverages contain information on various soil attributes that can be linked on the AEZCODE field in the PAT. The attributes are listed in Appendix A1.4.

Cautionary Notes:

- Matching problems occurred on the edges of the four soil association coverages of the Northwest region.
- The AEZ maps' database of soil parameters includes information as detailed as variants of particular soil series. Thus, for each soil association, there are several records in the database with different values for various soil parameters.

Map Accuracy: The soils coverages were digitized from 1:250,000 scale maps for national and regional use.

FAP 19 Archive Index: Tape serial no. T-19

A1.5 DEM

Title of the coverage/files: (Figure 5)
BDEM2.GIS: National coverage
BDEM2NW.GIS: Northwest regional coverage
BDEM2NE.GIS: Northeast regional coverage
BDEM2SW.GIS: Southwest regional coverage
BDEM2SE.GIS: Southeast regional coverage

Date Completed/Revised: October, 1994

File Format: ERDAS 16-bit GIS file, Arc/Info GENERATE (ASCII), SURFER (GRID, DAT)

Projection: Bangladesh Transverse Mercator

Source: BWDB topographic maps; 1:7920, 1:15840 scales

Digitizing Methods: The FAP 19 team interpreted and digitized the spot elevation data from the BWDB topographic maps by manually superimposing a transparent 500-m grid template on the maps and recording the elevation point nearest each grid intersection. Data entry into a dBASE IV data file was expedited with an interactive database application program. Following digitizing, the values were adjusted for datum differences, the elevation units were modified, and then converted into ERDAS DIG file format. The final step was the implementation of a spatial interpolation algorithm for transforming the point elevation data into a raster GIS image file. A detailed account of this process is found in the FAP 19 Technical Report "Medium Resolution Digital Elevation Model of Bangladesh".

Data Processing: Five primary DEM products were generated by this project: four with regional coverage (NE, NW, SE, SW) and one with nationwide coverage.

Cautionary Notes:

- The BWDB maps were compiled some 30 years ago and since then rivers have changed course and cut new channels, and chars have been washed away and others have formed. Due to these processes the DEM may be less accurate in close proximity to riverine environments.
- The numerous voids exist in the data set because: 1) The BWDB surveyed mainly agricultural land areas; geographic features such as rivers, *beels*, homesteads, forests, and steep terrain generally were not surveyed. 2) BWDB maps for certain areas were never published, were misplaced by custodian organizations, or were purposely unavailable for national security purposes.

Map Accuracy: The ERDAS GIS files have a 300-m pixel size and a 0.1-m elevation interval. However, the data resolution is 500-m horizontal resolution and 0.1-ft. vertical resolution.

FAP 19 Archive Index: Tape serial no. T-19

A1.6 BWDB Gauging Stations

A1.6.1 Water Level and Discharge Stations

Title of the coverage/file: WLQ_ST (Figure 7)

Date Completed/Revised: June 1992

File Format: ARC/INFO point coverage

Projection: Bangladesh Transverse Mercator

Source: BWDB, Surface Water Hydrology-II, hydrological network map; 1:750,000 scale

Digitizing Methods: FAP 19 digitized the locations of water level and discharge stations from BWDB hydrological network maps.

Data Processing: A spreadsheet consisting of station name, BWDB code number, and latitude and longitude was acquired from BWDB. FAP 19 added the following data to the spreadsheet: data availability for these stations, river names, and MPO one-day average maximum flood levels. The spreadsheet were then converted to dBASE IV format and added to the PAT of the monitoring station coverage.

Feature Codes: User-id's and attribute fields contained in the PAT follow:

User-ID	Type of Station
110	Existing hydrological stations (water level and discharge)
355	Existing hydrological stations (water level only)
1000	Selected existing hydrological stations (water level and discharge)
50103	Selected existing hydrological stations (water level only)
49004	Proposed hydrological stations (water level and discharge)
91605	Hydrology water level recorder
91606	BIWTA water level stations
215007	Selected water level stations where river discharge measurement is requested
142008	Hydrological stations equipped with a water level recorder (water level and discharge)
291009	BWDB tidal stations

Items	Descriptions
STNAME	Station name
RIVER	Name of corresponding rivers
STCODE	Code numbers of source map stations

Map Accuracy: Data were derived from a 1:750,000 scale map for use at the national level.

FAP 19 Archive Index: Tape serial no. T-1

A1.6.2 Rainfall Stations

Title of the coverage/file: RAINF_ST

Date Completed/ Revised: May 1993

File Format: Point coverage

Projection: Bangladesh Transverse Mercator

Source: BWDB provided tabular rainfall station data including geographic coordinates.

Digitizing Methods: The geographic coordinates (latitude/longitude) for rainfall station were transferred into an ASCII text file and a coverage was generated using the ARC/INFO GENERATE command.

Data Processing: The remaining attributes in the spreadsheet, including station name, district name, recorder type, elevation, and availability of flood forecasting, were added to the coverage PAT. Information on station type and equipment were later added to the coverage from a rainfall station map provided by FAP 10.

Feature Codes: The attributes fields from the PAT and their description:

Item	Description
RAINF_ST_I	User ID of the station
ST_NAME	Station names
DISTRICT	District name
TYPE	Recorder/ no recorder
PWD_EL	Platform elevation in meters
FORECAST	Flood hazard forecasting
MAP_SYN	Category of rainfall stations (follows)

MAP_SYN	Category of the Rainfall Stations
85	Rainfall stations
86	Automatic rainfall stations
87	Rainfall and evaporation stations
88	Automatic rainfall and evaporation stations
90	Forecasting rainfall stations with wireless
91	Forecasting automatic rainfall stations with wireless
92	Forecasting rainfall and evaporation stations with wireless
93	Forecasting automatic rainfall and evaporation stations with wireless
95	Forecasting automatic rainfall and evaporation stations without wireless
94	To be checked with the SWMC hygrometric station map

Cautionary Notes:

- The FAP 19 database includes 45 stations not shown on the BWDB hydrological network maps used to map the water level and discharge stations (above).
- Seven additional stations were found the BWDB hydrological network maps that were not included in the spreadsheet used to generate the coverage.

Map Accuracy: The reliability of the rainfall station coordinates is unknown. FAP-19 selectively checked six stations in the northwest region, seven in the northeast region, and five in the southwest region from 1:50,000 scale SOB maps. The locations were accurate within 1.5 cm on the maps (750 m on the ground).

FAP 19 Archive Index: Tape serial no. T-1

A1.7 Demography

Title of the Coverage/file: **UPAZILA** (included in the thana coverage PAT)

Date Completed/ Revised: December 1994

File Format: dBASE IV

Projection: Bangladesh Transverse Mercator

Source: BBS 1991 population census data.

Digitizing Methods: The 1991 population census data was entered into the PAT database file using dBASE IV for the Administrative Boundary File (Thana) described above.

Feature Codes: The PAT attributes include area, population, household, number of males, number of females, literacy rate for persons over seven years, and population over 18 years. The database field names and are listed below:

Field Name	Description
GEOCODE	Thana geo-code
UPZCODE	Thana code
UPZNAME	Thana name
AREA_ACR	Area in acres
HOUSEHOLD	Total number of households (1991)
HHOLD81	Total number of households (1981)
TOTAL POP	Total population (1991)
POP81	Total population (1981)
MAL91	Total male population (1991)
FEM91	Total female population (1991)
LIT7	Literacy rate over 7 years (1991)
POP18	Population over 18 years (1991)

Cautionary Notes:

- The BBS provided data for each metropolitan thana, but not for the entire city. Because the thana coverage contained only one polygon for each city, the respective values of some municipality areas for Dhaka, Chittagong, and Khulna were aggregated.
- It was noted that the 1991 census data indicates a decrease in population over the 1981 census in six thanas: Pabna in Rajshahi district, Nikley in Kishoreganj district, Daulatpur and Harirampur in Manikganj district, Janjira in Shariatpur district, and Panchhari in Khagachhari district. The recorded area of the thanas, however, is identical in 1981 and 1991. Thus, it is unclear why the population decreased.

Map Accuracy: Maximum 1:250,000; 1:500,000 or smaller is advised.

FAP 19 Archive Index: Tape serial no. T-19

A1.7.1 Population Density

The BBS 1981 and 1991 population census data were added to the thana coverage. Population density for 1981 and 1991, population density change between 1981 and 1991, and population density of persons over 18 years was calculated in dBase. The list and description of fields (density, density code) that were added to the Thana and District coverage PATs are shown in Tables 6 and 7.

Table 6 Population Density Attributes in the Thana Coverage PAT

Field Name	Description	Source
AREA	Area in sq. m	ARC/INFO generated
AREA_SQKM	Area in sq. km.	AREA / 1,000,000
POP81	Total population of 1981	BBS
TOTALPOP	Total population of 1991	BBS
POPDENS91	Population density per sq. km. (1991)	TOTALPOP / AREA_SQKM
DENSCODE91	Population density code (1991)	See DN91SHD.KEY
POPDENS81	Population density per sq. km. (1981)	POP81 / AREA_SQKM
DENSCODE81	Population density code (1981)	See DN81SHD.KEY
POPDIF8191	Total population change (1981-1991)	TOTALPOP - POP81
POPDENDIF	Population density change (1981-1991)	POPDENS91 - POPDENS81
PPDNDIFCOD	Population density change code	See DNDIFSHD.KEY
POP18DENS	Population density of persons over 18 years (1991)	POP18 / AREA_SQKM
POP18DNCODE	Population density of persons over 18 years code	See DN18SHD.KEY

Table 7 Population Density Attributes in the District Coverage PAT

Field Name	Description	Source
AREA	Area in sq. m	ARC/INFO generated
AREA_SQKM	Area in sq. km	AREA / 1,000,000
POP81	Total population of 1981	BBS
POP91	Total population of 1991	BBS
POPDENS81	Population density by district (1981)	POP81 / AREA_SQKM
POPDENS91	Population density by district (1991)	POP91 / AREA_SQKM
DENSCODE81	Population density code (1981)	see DN81SHD.DBF
DENSCODE91	Population density code (1991)	see DN81SHD.DBF

A1.7.2 Households

Household densities (households per sq. km.) for 1991 and 1981 were calculated and classified into codes using dBASE IV. The list and description of fields that were attached to the Thana coverage PAT and the formula used for calculating the value of each field follows in Table 8.

Table 8 Household Attributes in the Thana Coverage PAT

Field Name	Description	Formula Used for Calculation
HOUSEDENS	Household density per sq. km. (1991)	(HOUSEHOLD/AREA_SQKM)
HSDNCODE	Household density code (1991)	See HSDNSHD.KEY
HHDEN81	Household density per sq. km. (1981)	(HHOLD81/AREA_SQKM)
HSDNCODE81	Household density code (1981)	See HSDN81.KEY

A1.8 Flood Inundation Land Type (Flood Depth)

Title of the coverage/file: **BDLTYPE**

Date Completed/Revised: May 1995

File Format: ERDAS 8-bit GIS file, ARC/INFO polygon coverage.

Projection: Bangladesh Transverse Mercator

Source: FAP 19 National Database: soils and topography data themes as described above.

Digitizing Methods: This data layer was not digitized, rather it is a by-product generated from two of the primary data sources described above. It is a digital map showing average flood depth created through the integration of soils and topographic information using GIS spatial analysis.

Data Processing: The spatial analysis performed to create these data is complex and involved. Please refer to section 3.8 of this document for information on data processing.

Features: Flood Depth as MPO classes (F_0-F_4)

Cautionary Notes: Flood depths supplied by these maps are based on general soil association map units and represent only average depths which occur during normal flood years.

Map Accuracy: The ERDAS file and coverage are intended for national and regional use.

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APPENDIX 2: DATA CONVERSION FORMATS

The National Database themes can be converted to and from any of the formats listed below using native ARC/INFO programs.

A. VECTOR FORMATS

- **ATLAS:** ATLAS *GRAPHICS export format file (.BNA file) containing data extracted from Strategic Locations Planning ATLAS*GRAPHICS desktop mapping package.
- **GBA/DIME:** Dual Independent Map Encoding format file containing geographic coordinates of line segments and census area code. It was used by the U.S. Bureau of Census for the 1980 census.
- **DLG-3:** Digital line graph format file used by the U.S. Geological Survey with coordinate transformation.
- **DLGN-3:** Digital line graph format file used by the U.S. Geological Survey without coordinate transformation.
- **DXF:** AutoCAD ASCII Drawing Interchange format file.
- **ETAK:** Etak MapBase files are similar to DIME format files. Each record represents a single linear feature with addresses and census information.
- **IGES:** Initial Graphics Exchange Standard (version 3.0 uncompressed ASCII format file) published by the U.S. Department of Commerce.
- **MOSS:** Map Overlay Statistical System format file readable by the U.S. Department of Interior's MOSS public domain GIS.
- **TIGER:** Topologically Integrated Geographic Encoding and Referencing system used by the U.S. Bureau of Census to support census programs and surveys.

B. RASTER FORMATS:

- **Noncompressed ASCII:** Stores one attribute code for each grid cell on a cell by cell basis.
- **Compressed ASCII:** Stores one attribute code for each group of contiguous cells having the same code value.
- **ERDAS 8-bit data:** A binary file that stores cell values as one byte per pixel.
- **ERDAS 16-bit data:** A binary file that stores cell values one two bytes per pixel.
- **EPPL7:** A binary file that stores cell code values by cell position.
- **GRID Card Image:** An ASCII file that stores one attribute code for each cell according to a specified format.
- **MIDAS:** Map Information Assembly Display System.

APPENDIX 3: CONVERTING TYDAC SPANS DATABASES TO ARC/INFO

SPANS is a raster-based GIS software package with some vector capabilities. There is no direct import/export format to exchange data from SPANS to ARC/INFO. However, SPANS can create VEC and VEH files (ASCII format) for each of the SPANS themes. A VEH file is a header file containing information on feature type, map extent, projection system, and reference point (tic) coordinates. A VEC file, or vector file, contains information on vertex coordinates, attribute codes, and starting and ending node coordinates for lines or coordinates of point. The VEC files can be created with vector coordinates in any specified coordinate system.

Because there was no direct import facility from SPANS to ARC/INFO, FAP 19 developed a program in PASCAL to read the vertex coordinates of any feature in SPANS ASCII format (VEC and VEH files) and convert it into ARC/INFO GENERATE (ASCII) format. The ARC/INFO GENERATE file were in turn used to create coverages. The conversion program assumes that the input file coordinate system is Lambert conformal conic (Indian Grid IIB, yards), the cartographic projection used by AST. Thus, once in ARC/INFO coverage format, the data was projected to BTM.

APPENDIX 4: TECHNICAL NOTE NO. 1 - BANGLADESH TRANSVERSE MERCATOR PROJECTION

SUMMARY

FAP 19 has adopted a Transverse Mercator projection for all its digital mapping in Bangladesh. This projection is based on that in use by FAP 18 (Topographic Mapping). This projection is proposed for use by others in the Flood Action Plan.

Tentative Name	:	Bangladesh Transverse Mercator (BTM)
Projection	:	Transverse Mercator
Ellipsoid	:	Everest 1830
Scale Factor	:	0.9996
Central Meridian	:	90^{O} E
Latitude of Origin	:	0^{O} (Equator)
False Easting	:	500,000
False Northing	:	-2,000,000

BACKGROUND

FAP-19's Geographic Information System records and stores geographically referenced information in its computers in an X-Y (Cartesian) coordinate system. In this system the X axis is always orthogonal to the Y axis -- as in standard numerical tables. However, for collecting and storing these data digitally and for generating maps that display these data, the curvature of the earth's surface must be accounted for, which introduces spatial distortions.

Historically, a variety of mathematical adjustments, known as "projections", have been used to minimize different types of distortions in converting from spherical coordinates, such as longitude and latitude, to Cartesian coordinates. Such a projection is the mathematical process of converting these spherical coordinates to Cartesian coordinates or to "developable" [flat] surface representations such as maps. The best projection for a given area is usually the one that minimizes the amount of distortion over the area of interest while preserving certain relationships such as direction or areal consistency.

Different projections are commonly used for different parts of the earth and for different sizes and shapes of areas. A review of two of the more common map projections in Bangladesh, Universal Transverse Mercator and Lambert Conformal Conic, reveal limitations in their use for digital mapping of Bangladesh; both of these projections were intended for large areas and show significant distortions when applied to the territory of Bangladesh.

This technical note describes limitations of these projections for Bangladesh and presents a new projection that has been adopted by FAP-19 for the construction of its National Database and for all other applications. This projection will facilitate the accurate recording of geographical information and its exchange with other FAP projects and Bangladesh agencies.

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MAP PROJECTIONS IN BANGLADESH

Many historic surveys in Bangladesh were mapped using the India Zone IIB yards grid system (India Zone IIB yards for the southern half of the Chittagong Hill Tracts). This grid zone is based on a Lambert Conformal Conic projection. The projection creates a conical surface that intersects the earth at the single standard parallel of 26^{O} N latitude (17^{O} N for Zone IIB). With this projection, distortions east and west are minimized but increase with distance north and south of the 26^{O} parallel. The projection is used by the Survey of India for creating maps of a vast east-west extent of the Indian sub-continent but is not optimal for Bangladesh, which is longer than it is wide and mostly lies south of the 26^{O} parallel.

The Universal Transverse Mercator (UTM) projection is commonly used throughout the world, including some mapping and applications in Bangladesh. The UTM is based on the Transverse Mercator projection and the geocentric ellipsoid WGS84. This projection portrays a horizontal cylinder intersecting the earth along a "central" north-south meridian. Its spatial distortions increase from the central meridian in east-west directions. Maps in this projection are most accurate in tropical latitudes and result in increasing spatial exaggerations where the great circles of longitude converge near the poles. The UTM projection portrays a series of horizontal cylinders tangent to the earth along equally spaced meridians. The UTM system divides the world into sixty such north-south zones, each 6^{O}s wide. Bangladesh is divided almost equally between two UTM zones, one east of 90^{O} E longitude and one west of that meridian. Therefore, the UTM projection requires use of two different transformations for dealing with spatial data from the two zones of Bangladesh.

To reduce the average spatial distortion over a UTM zone, a horizontal Scale Reduction Factor (SRF) is introduced. This factor effectively creates two north-south lines of no scale distortion, "lines of true scale". These are 1.5^{O}s either side of the central meridian. This has the effect of slightly shrinking the area between the "lines of true scale" and slightly increasing areas beyond these lines. The overall effect is to balance the spatial distortion for the entire UTM zone. The standard SRF for a 6^{O} UTM zone is 0.9996.

ELLIPSOID

Another important factor for mapping and digital databases is an appropriate map datum. Since the surface of the earth is not a smooth ellipsoid mathematically convenient for accurately representing all regions of the earth, different models of the surface have been developed for use in different regions. The geocentric WGS84 model best represents the entire earth but with less overall accuracy for the Indian subcontinent. Historically, the Everest ellipsoid has been used on the Indian subcontinent and provides the "best fit" for this part of the world.

BANGLADESH TRANSVERSE MERCATOR (BTM) PROJECTION

A cylindrical Transverse Mercator projection and the Everest ellipsoid have been selected for use with the FAP-19 databases. This projection, tentatively termed Bangladesh Transverse Mercator (BTM), is currently used by FINNMAP to map selected portions of Bangladesh under FAP 18 (Topographic Mapping) and other activities. Rather than dissecting the country into two zones, as with UTM, the BTM takes 90^{O} its central meridian and projects a 6^{O} wide zone on that meridian. All of Bangladesh is contained within this zone, which extends from 87^{O} to 93^{O} E.

Most existing cartographic data in Bangladesh, including recently printed SPOT satellite image photomaps, is based on the Everest ellipsoid. While consideration may be given to the use of other models in the future, at the moment the Everest ellipsoid is satisfactory for our purposes.

The same Scale Reduction Factor (0.9996) that is used by UTM is applied to the FAP-19 data bases. Meridians of $88^{O}30'$ and $91^{O}30'$ represent "lines of true scale". This SRF is appropriate for TM zones of 6^{O}.

To aid in field location, FAP-19 has adopted a metric grid that covers all of Bangladesh. The X-Y coordinates of this grid are established by designating a "false easting" of 500,000 meters and a "false northing" of -2,000,000 meters from its origin at 0^{O} N (equator) and 90^{O} E. With this grid, all locations in Bangladesh may be identified by positive X and Y values ranging between 0 and 999,999.

CONCLUSION

FAP-19 is using the Bangladesh Transverse Mercator projection based on the 90^{O} central meridian and the Everest ellipsoid to prepare its computerized National Database and for all other applications. This projection is suggested for use by other FAP activities which will enable direct transfer of digital data among computer-based mapping and geographic information systems.

FAP-19 will be pleased to assist other organizations in using this projection and in converting to/from other projections in use in Bangladesh.

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APPENDIX 5: SOIL ASSOCIATION COVERAGE ATTRIBUTES

The source maps for the FAP 19 digital soils coverage and its accompanying attribute data set in were originally produced by the AEZ Land Resources Appraisal. The attributes, in spreadsheet format include soils, climate, and flood characteristics. FAP 19 converted the data to dBASE IV format and linked them to the soil coverages database tables (PAT). The attributes are described below.

Soil Taxonomic Codes:

AEZCODE: Soil Association Map Code

Alpha-numeric soil map unit codes as given in the AEZ Land Resources Appraisal maps (Report 5, Volume II, UNDP-FAO, 1988).

SERNUM: Soil Series Number

A soil series is a group of soils formed in the same parent material, with a similar arrangement of soil horizons and physical characteristics (e.g., subsoil texture, color, structure, pH).

A total of 574 soil series have been inventoried together with their areal extent, landform, physical, and chemical characteristics.

VARNUM: Soil Variant Code

A soil series may include one or more soil variants which generally possesses one physical or chemical characteristic which differs from the soil series definition, e.g., color, structure, etc. The soil variant code is related to the soil series number.

PHASE:

Soil series are further classified into *soil phases*, which are differentiated according to practical land use considerations and are the most specific homogenous component of a soil association.

Landform Characteristics :

LANDTYPE: Land Type (Inundation Land Type) [LT]
In Bangladesh, six basic inundation land types are recognized by the symbols: H, MH1, MH2, ML, L, and VL. Each relate to the normal range of flood depths during the peak rainfall period of the *kharif* (wet) season, and correspond approximately with peak discharges of the river systems.

The basic inundation land types are further differentiated depending on whether or not they remain as wetlands throughout the *kharif* and *rabi* seasons. Land which is inundated in the *kharif* season and remains a wetland during the rest of the year, including the dry *rabi* season, is referred to as bottomland (i.e., MH1b, MH2b, MLb, Lb, VLb). Thus, there is a total of 11 land types based on the surface hydrological conditions during the *kharif* and *rabi* seasons (Table 9).

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RELIEF: Relief (RE)

Land relief has been inventoried as five categories, as follows.

Code	Description
1	Regular
2	Irregular
3	Broadly dissected
4	Closely dissected
5	Deeply dissected

Table 9 Inundation Land Type

Code	Symbol	Land Type	Description
1	H	Highland	Land which is above normal inundation level
2	MH1	Medium Highland 1	Land which normally is inundated less than 30 cm deep
3	MH1b	Medium Highland 1- Bottomland	As above but remains in a wetland state throughout the year
4	MH2	Medium Highland 2	Land which normally is inundated in the range 30-90 cm deep
5	MH2b	Medium Highland 2-Bottomland	As above but remains in a wetland state throughout the year
6	ML	Medium Lowland	Land which normally is inundated in the range 90-180 cm deep
7	MLb	Medium Lowland-Bottomland	As above but remains in a wetland state throughout the year
8	L	Lowland	Land which normally is inundated in the range 180-300 cm deep
9	Lb	Lowland-Bottomland	As above but remains in a wetland state throughout the year
10	VL	Very Lowland	Land which normally is inundated more than 300 cm deep
11	VLb	Very Lowland-Bottomland	As above but remains in a wetland state throughout the year

SLOPE: Slope (SL)

The following six slope classes are categorized:

Code	Slope (%)
1	<3
2	3-8
3	8-16
4	16-30
5	30-45
6	>45

EROSION: Erosion Status (ES)

Erosion was divided into the following two classes:

Code	Description
1	Topsoil not eroded
2	Topsoil eroded

Physical Characteristics of the Soil Series:

TOPTEX: Topsoil Texture (TX)

Code	Description
1	Clay
2	Clay Loam
3	Fine Sandy Loam
4	Gravelly Clay Loam
5	Gravelly Sandy Clay Loam
6	Loam
7	Loamy Fine Sand
8	Loamy Sand
9	Muck
10	Mucky Clay
11	Peaty Muck
12	Sand
13	Sandy Clay Loam
14	Sandy Loam
15	Silt
16	Silty Clay
17	Silty Clay Loam
18	Silt Loam
19	Very Fine Sandy Loam
20	Peaty
21	Mixed
22	No Data

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EFFDEPTH: Effective Soil Depth (SD)

Code	Depth (cm)	Description
1	<25	Very shallow soil
2	25 - 60	Shallow soil
3	60 - 90	Deep and very firm soil
4	90 - 122	Deep and firm soil
5	> 122	Deep and friable soil

PAN: Ploughpan (PP)

Presence or absence of very firm/hard ploughpan.

Code	Description
1	Absence of ploughpan
2	Presence of ploughpan

SOILMOIST: Soil Moisture (SM)

Available moisture-holding capacity (AMHC).

Code	Capacity (mm)	Description
1	<100	Very low AMHC
2	100-200	Low AMHC
3	200-300	Moderate AMHC
4	300-400	High AMHC
5	>400	Very high AMHC

PERM: Soil Permeability (SP)

Code	Rate(cm/day)	Description
1	<12	Slowly permeable
2	23-305	Moderately permeable
3	>305	Rapidly permeable

DRAIN: Drainage (DR)

Code	Description
1	Well to excessively drained
2	Moderately well drained
3	Imperfectly drained
4	Poorly drained but surface drains early (before mid-November)
5	Poorly drained but surface drains late (after mid-November)
6	Very poorly drained

CONSIST: Soil Consistency/Workability (SC)

Code	Description
1	Mineral surface soil, not more than slightly firm, slightly sticky, slightly plastic, slightly hard.
2	Mineral surface soil firm, very firm, sticky, plastic, hard, very hard.
3	Mineral surface soil, extremely firm, very sticky, very plastic, extremely hard.
4	Organic soil, organic material to at least 25 cm below the surface.

Chemical Characteristics of the Soil Series:

REACTION: Soil Reaction (pH)

Code	pH	Description
1	<4.5	Extremely acid
2	4.5-5.5	Strongly to very strongly acid
3	5.5-7.3	Neutral to moderately acid
4	7.3-8.4	Mildly to moderately alkaline
5	>8.4	Strongly to very strongly alkaline

NUTRIENT: Nutrient Status (NS)

Natural nutrient status.

Code	Description
1	Low: relatively infertile
2	High: relatively fertile

SALINE: Soil Salinity (SS)

Code	EC (mmhos/cm)	Description
1	<2	Non-saline
2	2-4	Very weakly saline
3	4-8	Weakly saline
4	8-15	Moderately saline
5	>15	Strongly saline

ALKALINE: Alkaline Phase (AL)

Code	Description
1	Alkali phase absent
2	Alkali phase present

CALCIC: Calcic Phase (CA)

Used only for soils with a petrocalcic horizon.

Code	Description
1	Calcic phase absent
2	Calcic phase present

ACID: Acid Sulphate Phase (AS)

Code	Description
1	Acid sulphate phase absent
2	Acid sulphate phase present

Inundation/Flooding Status

FLOODEPTH: Flooding Depth (FD)

In Bangladesh, six basic hydrological land types are recognized, each related to a specific range of inundation depths during the *kharif* seasons. These categories are related to the inundation land type categories (LT) (Table 10).

Table 10 - Flood Depth Categories

Code	Land type	Description
1	Highland (H)	Land not normally inundated.
2	Medium Highland 1 (MH1)	Normal inundation less than 30 cm.
3	Medium Highland 2 (MH2)	Normal inundation, 30-90 cm range.
4	Medium Lowland (ML)	Normal inundation, 90-180 cm range.
5	Lowland (L)	Normal inundation, 180-300 cm range.
6	Very Lowland (VL)	Normal inundation, 300 cm.

Hazard Characteristics:

Data on three types of flood hazards were collected by the SRDI reconnaissance soil survey reports: flood hazard, river erosion hazard, and storm surge hazard. Additionally, hazard frequency is given as a percentage of the years one of these hazards will occur.

FLOODHAZ: Flood Hazard (FH)

Code	Description
1	Disastrous flood hazard absent
2	Disastrous flood hazard present

EROSHAZ: Erosion Hazard (RH)

Code	Description
1	Disastrous river erosion hazard absent
2	Disastrous river erosion hazard present

SURGEHAZ: Storm Surge Hazard (SH)

Code	Description
1	Disastrous storm surge hazard present
2	Disastrous storm surge hazard present

HAZFREQ: Hazard Frequency (HF)

Code	Description
1	< = 2%
2	2 - 6%
3	6 - 20%
4	20 - 50%
5	> = 50%

Land Phase:

LANDAREA: Land Phase Area

The total area in hectares within a given soil phase excluding homestead, water bodies, and miscellaneous land area as described below.

HOMWATAREA: **Homestead and Water Area**
The area in hectares within a soil phase that is associated with settlements and perennial water bodies.

MISLNDAREA: **Miscellaneous Land Area**
The area in hectares within a soil phase that is associated with the following miscellaneous land cover categories: charland, mud-charland, saline, mud-charland, mud, mud flats, beach ridges, beach sand, forest, river *beel*, urban areas, unsurveyed areas.

ASSIGNING DOMINANT ATTRIBUTES TO SOIL ASSOCIATION MAP UNITS

When linking the dBASE IV file containing the attributes described above with the FAP 19 soils coverage, AEZCODE is used as the common field. Occasionally, however, more than one database record exists for each AEZCODE because of varied soil parameters within the delineated soil boundaries. FAP-19 devised two methods to solve this problem: weighted average and hierarchical methods.

Weighted Average Method

The key field for weighting is the soil series area. In this method the ratio of each series area to the soil association area is multiplied by the soil parameter code for all of the series in an association. The weight values are then summed. The resulting code is the soil parameter code of the soil association. The following equations are used:

$$\text{Output Code} = a_1/A_s*c_1 + a_2/A_s*c_2 + \ldots\ldots\ldots\ a_n/A_s*c_n$$

where
a_1 is the area in ha of each soil series given in AEZ database
$A_s = (a_1 + a_2 + \ldots\ldots\ldots\ldots\ldots a_n)$
c_1 is the code number of the theme we are interested.

Note that this method is only valid with attributes having ordinal categories. The method cannot be used with attributes having nominal categories such as RELIEF.

Hierarchical Method

The hierarchical method involves a three step process:

1) If 66.7 percent or more of a soil association is composed of a single attribute class (i.e., Highland for Land Type), then it can be classified as possessing this attribute.
2) If two sequential attributes make up 66.7 percent or more of a soil association (i.e., Highland + Medium Highland for Land Type), then it can be classified as a combined attribute class.
3) If the conditions in either 1) or 2) are not met, then the soil association will be classified as "mixed."

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