FLOOD RISK MAPPING IN KADUNA METROPOLIS USING SPOT XS SATELLITE DATA.

By

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(M. TECH / SSSE / 924 / 2003 / 2004)

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June, 2005

DECLARATION

This is to certify that I, Ebenezer O. Dania (Reg. No. M.TECH/SSSE/924/2003/2004), carried out this project, titled "FLOOD RISK MAPPING IN KADUNA METROPOLIS USING SPOT XS SATELLITE DATA" . It is part of the requirement for the Award of the degree of Master of Technology (M. Tech.) in Remote Sensing Applications programme of the Department of Geography, School of Science and Science Education, Federal University of Technology, Minna, Nigeria.

E.O. Dania .... 02 – 03 – 2006 ....

EBENEZER O. DANIA **DATE**

CERTIFICATION

I certify that EBENEZER OLAFIMIHAN DANIA (REG. NO: M. TECH / SSSE / 924/2003/2004),duly carried out this project titled "Flood Risk Mapping in Kaduna Metropolis Using SPOT XS Satellite Data". under my supervision. It satisfies the condition for the award of the degree of Master of technology (M. Tech.) in Remote Sensing Applications Programme of the Department of Geography, School of Science Education, Federal University of Technology, Minna, Nigeria.

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DR. S. MASHI EXTERNAL EXAMINER	**DATE**
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PROF. J. A. ABALAKA (DEAN, POST GRADUATE SCHOOL)	**DATE**

DEDICATION

This project is dedicated to my loving wife Kike, my children Emmanuel, Peter, Samuel and Patience for their patience and understanding. Finally to God the Father of our Lord Jesus Christ for his Faithfulness upon my life.

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ABSTRACT

This project demonstrates the application of Remote Sensing and geographical Information System in Mapping areas under the threat of land degradation as a result of flooding in Kaduna metropolis.

SPOT XS Multispectral satellite data was used to obtain information layers such as settlements, drainages, roads of the study area which served as input into a Geographical Information System (GIS). Surface data was obtained through manual digitization of topographical map of the study area to generate a Digital Terrain Model (DTM). Also GPS heights were taken at maximum flood limits from field surveys to create a buffer zone of the study area.

The analyzed image data layers, digital Terrain model, the GPS flood limit heights were dropped by GIS technique to have a perspective view (Flood Model).

The final results that is the flood risk zones (map) and the attribute table showing flood risk zones could thereby serve as a viable input to policy makers in management of land degradation problems in the study area.

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CHAPTER ONE

INTRODUCTION

1.1 Background

Among all kinds of environmental hazards of the world, flood is probably the most devastating, wide spread and frequent. Flood occurs when the capacity of the few drainage channels available to contain flood water is exceeded. The introduction of cement led to indiscriminate constructions of houses thereby concreting city surfaces that leads to decreased infiltration and consequent increase in run-off volumes. This practice has contributed immensely to occurrence of severe flooding events in Kaduna metropolis, the study area. Furthermore, distortion of master plan by dwellers, deforestation of forested area along the Kaduna river area leads to the increase flood content. Remote sensing as an information generation technology has provided mankind with an enhanced opportunity to appraise, monitor and model their natural resources. This technology has been enhanced with improvement in spatial resolution of commercial satellite imageries especially Landsat TM, SPOT (P-model), Quickbird and Ikonos with spatial resolutions of 30m, 10m, 0.61m and 0.81m respectively. Remote sensing can therefore be put to best use if incorporated into Geographical Information System (GIS).

Ehlers (1997) defined GIS as a powerful set of tools for collecting, storing, manipulating, analyzing and displaying the spatial data derived from a variety of sources according to user – defined specifications. One major advantage of GIS is the ability to overlay various layers of spatially referenced data to obtain customized maps.

1.2 Problem Statement

Flood is indeed a major problem posing great challenges to development efforts in the flood prone areas along the inhabited plain of river Kaduna within Kaduna metropolis.

For the last two decades, advancement in the field of remote Sensing and Geographical Information Systems (GIS) techniques have proved to be good and useful tools in the operation of flood mapping and flood risk assessment at both macro and micro levels worldwide. Despite this, not much research information is available that demonstrates the extent to which flood risk mapping can be carried out using SPOT XS satellite data and GIS application in the study area (Fig.1.1).

With an ever increasing awareness of the need to protect and preserve the resources of the environment, and the need to be more environment – friendly flood is seen today as a threat to man and his environment more than ever before of its dire consequence.

The concept of SPOT multi, spectral imageries, were also used for flood delineation with the similar assumption that water has very low reflectance in the near infrared portion of the spectra. SPOT imageries, for example, were used along with a DEM for delineation of monsoon flood in Bangladesh (Brouder, 1994: Oberstadler et al, 1997; Profeti et all, 1997, Sado et al., 1997).

The study area is one of the major flood prone areas in Kaduna and for development planning, sustainable resources and hazard management, there is the need to map areas under the threat of land degradation as a result of flooding.

The problem of research interest to this study therefore to show how this can be done.

1.3 Aim And Objectives

1.3.1 Aim

The main project is to use remotely-sensed SPOT XS satellite image in geographical information system (GIS) to map out areas under the threat of of flooding by the River Kaduna of Kaduna metropolis. To achieve this aim, the following objectives are to be pursued:

1.3.2 Objectives

(i) Using the pre-processed SPOT multi – spectral (XS)digital satellite image data to highlight the various flood-related features interest such as settlements, streams/river(drainages) and roads.

(ii) To generate Digital Terrain Model (DTM) of the study area by manual digitizing of elevations from topographical map of the study area.

(iii) To design and create a topographical spatial database of the study area by GIS technique.

(iv) To obtain a composite map in 3 – D as a result of overlays of the layers of information showing flood-prone areas of the study area.

1.4 Justification of Study

Environmental hazards such as erosion and flood types are having much negative effect on agricultural lands, urban lands and roads. Kaduna metropolis is faced with devastating occurrence of seasonal flood which have become rampant resulting in many lives and properties worth millions of naira being lost and damaged. The occurrence resulted from man's interference with the environment through urbanization.

Furthermore, the environmental problems of erosion and flood types leading to the frequent outbreak of epidemics such as cholera, typhoid fever and gastro- intestinal problems. It is therefore important to map areas which may continue to experience future hazards to serve as a viable input to policy – makers in management of land degradation problems in the study area.

1.5 Study Area

1.5.1 Geographic Location

The study area (Fig.1.1) is defined by the following geographical coordinates: (10° 37' 00"N, 7° 22' 00"E); (10° 37' 00"N, 7° 30' 00"E). (10° 29' 00" N, 7° 22' 00"E). It occupies a land area of about 20,000 hectares and has a population of over 500,000 (N.P.C.,1998) people with an estimated annual growth rate of 2.83% (N. P. C., 1998).

1.5.2 Climate

The area experiences savanna climate of dry and wet season annually. A major factor responsible for the climatic variations in Kaduna metropolis and which affects all climate elements is the seasonal movement of the inter-tropical discontinuity (ITD) or the Inter Tropical convergence zone (ITCZ) which is the meeting zone of the two principal air masses that prevail in Nigeria. It is the movement of the ITD that is responsible for the two marked seasons experienced in Kaduna. The southern location of the ITD brings

Kaduna metropolis under the influenced of the continental air mass referred to as North easterly or harmattan winds, which are dry, dusty and contain no moisture blowing from across the Sahara Desert. The air mass prevails in the country during the dry season and lasts from November to March. The South – Westerly wind blowing from the Atlantic Ocean inland is as a result of the northern location of the ITD which brings Kaduna metropolis under the influence of the tropical maritime air mass (MT). These winds are moisture laden and are responsible for the wet March / April and October.

1.5.3 Rainfall

Figure 1.2 shows that the study area received an average of 1312.9mm rainfall annually during the wet season (April to September) spread over a period of 6 months.

1.5.4 Temperature And Humidity

The area experiences high temperatures all the year as shown in the bar graph(Fig.1.3). The mean annual temperature is about 32.2 °C. recorded for five (1999-2003) years duration.

The annual mean relative humidity recorded for five (1999-2003) years is shown in the bargraph (fig.1.4) is 53.5%.

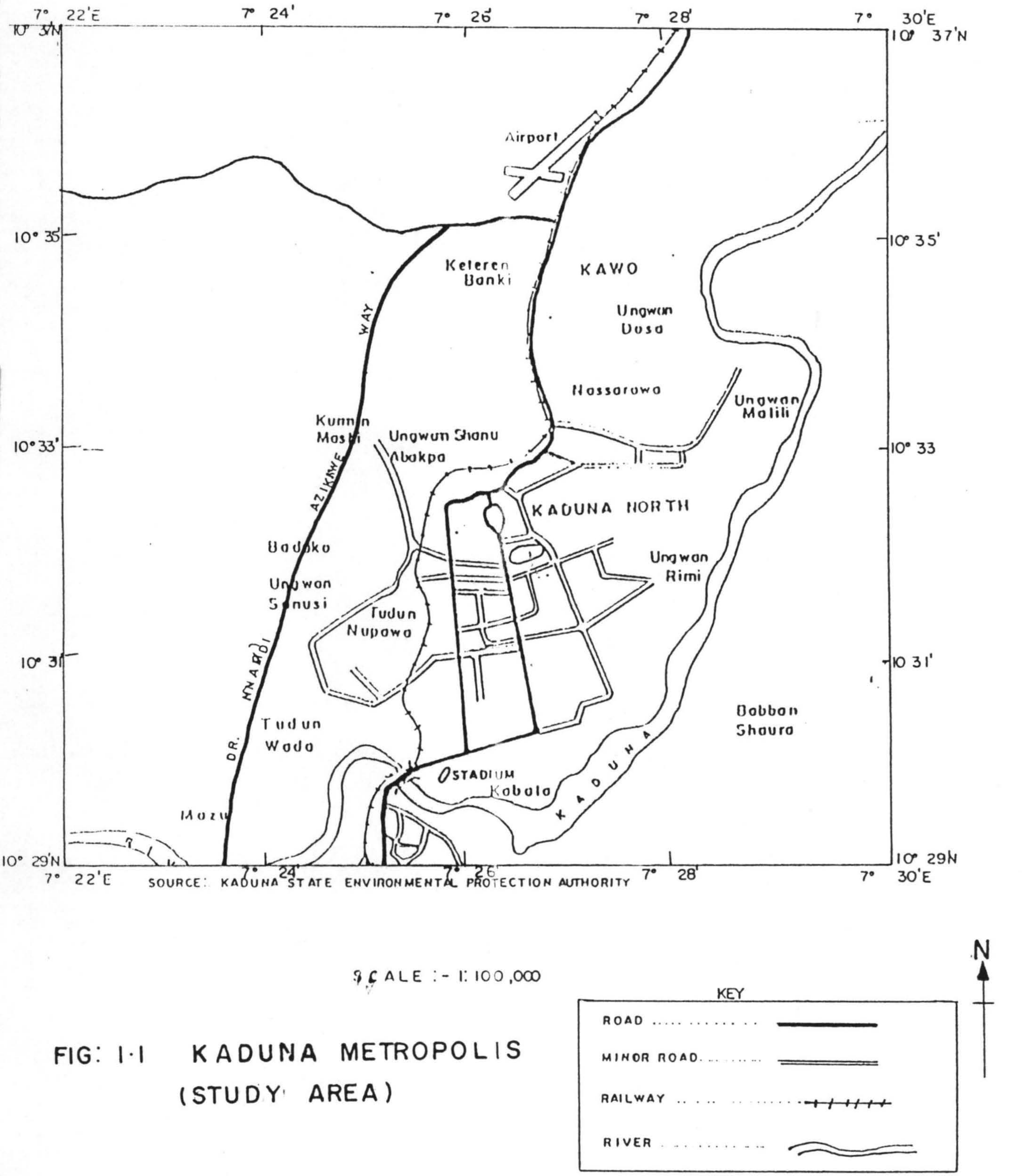
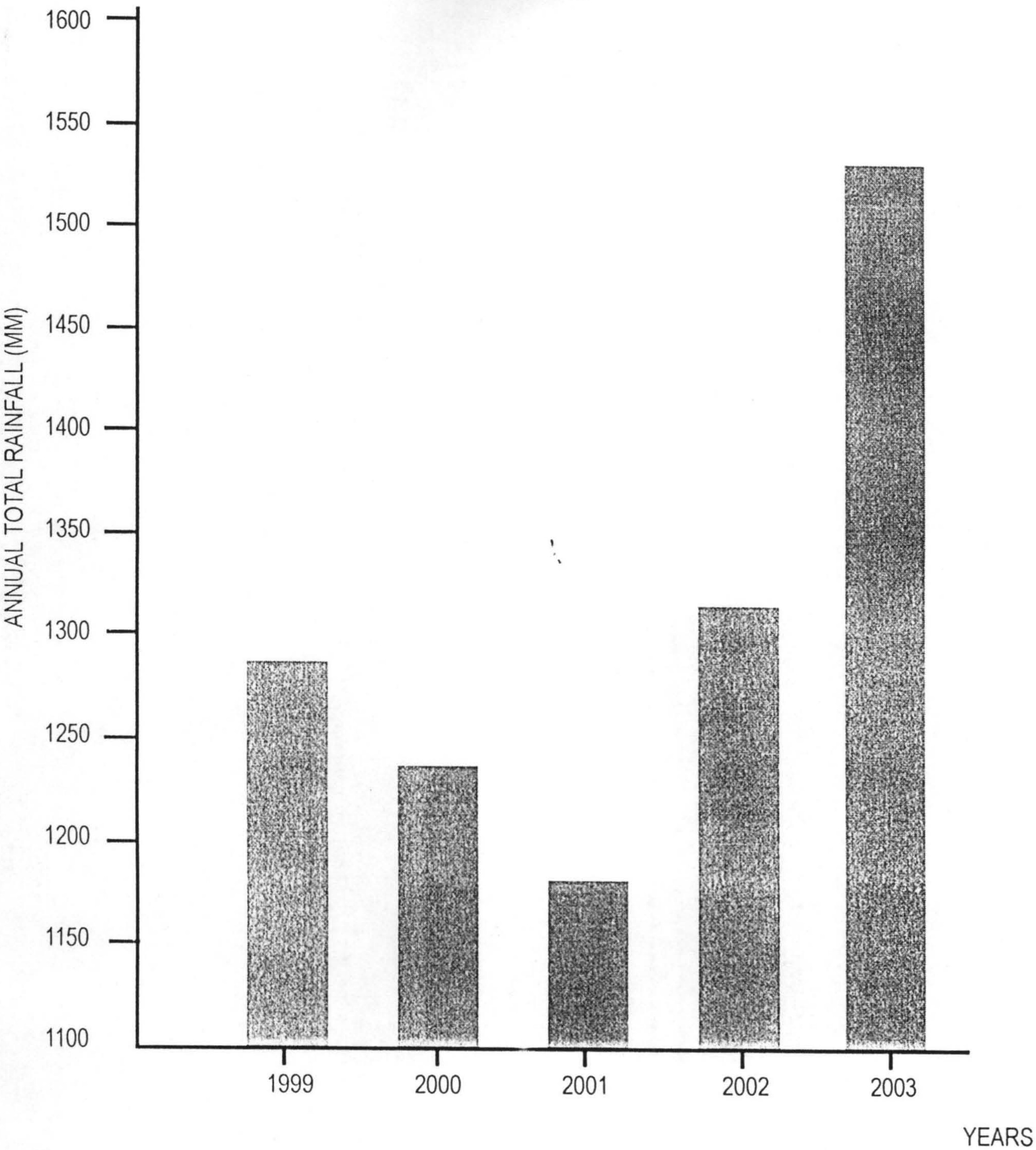
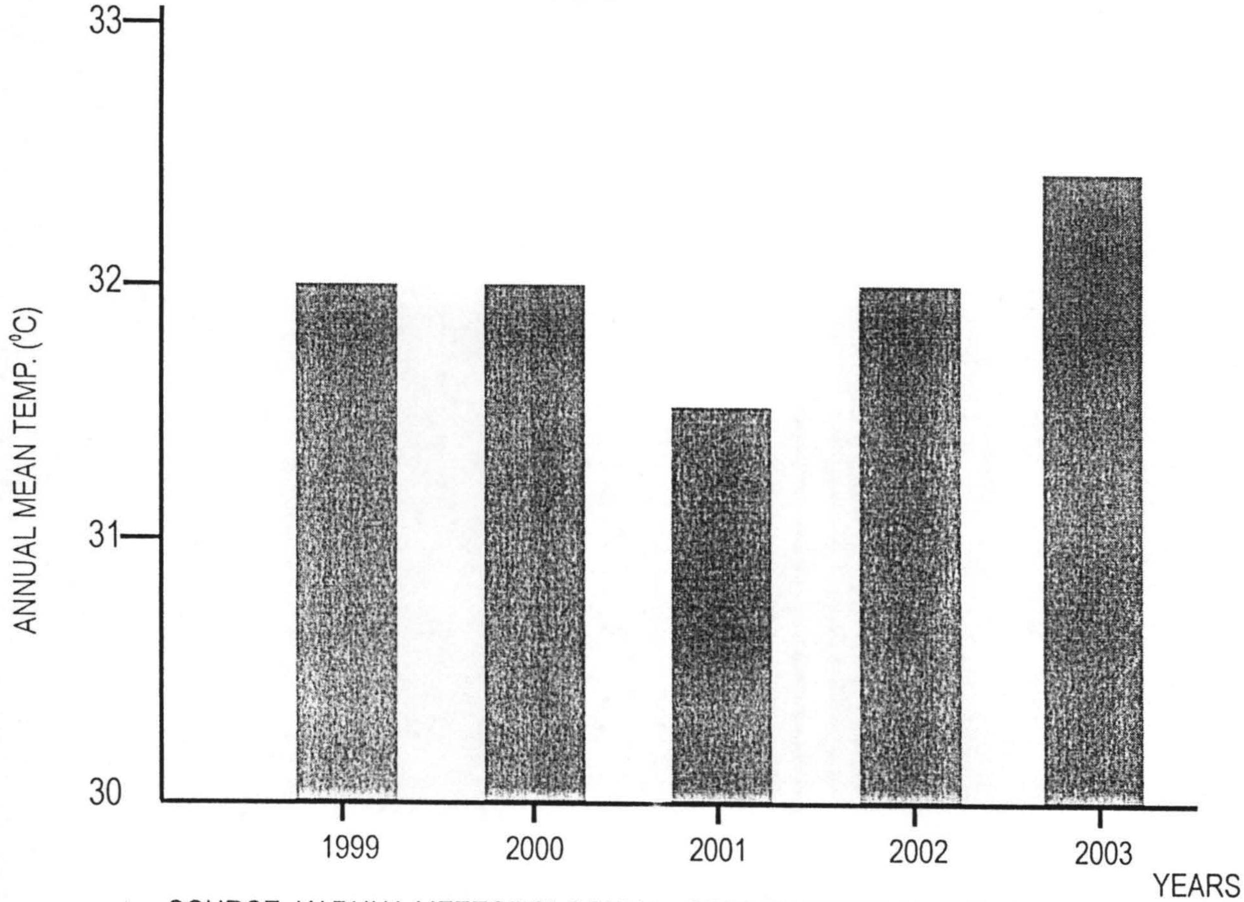


FIG: 1·1 KADUNA METROPOLIS (STUDY AREA)



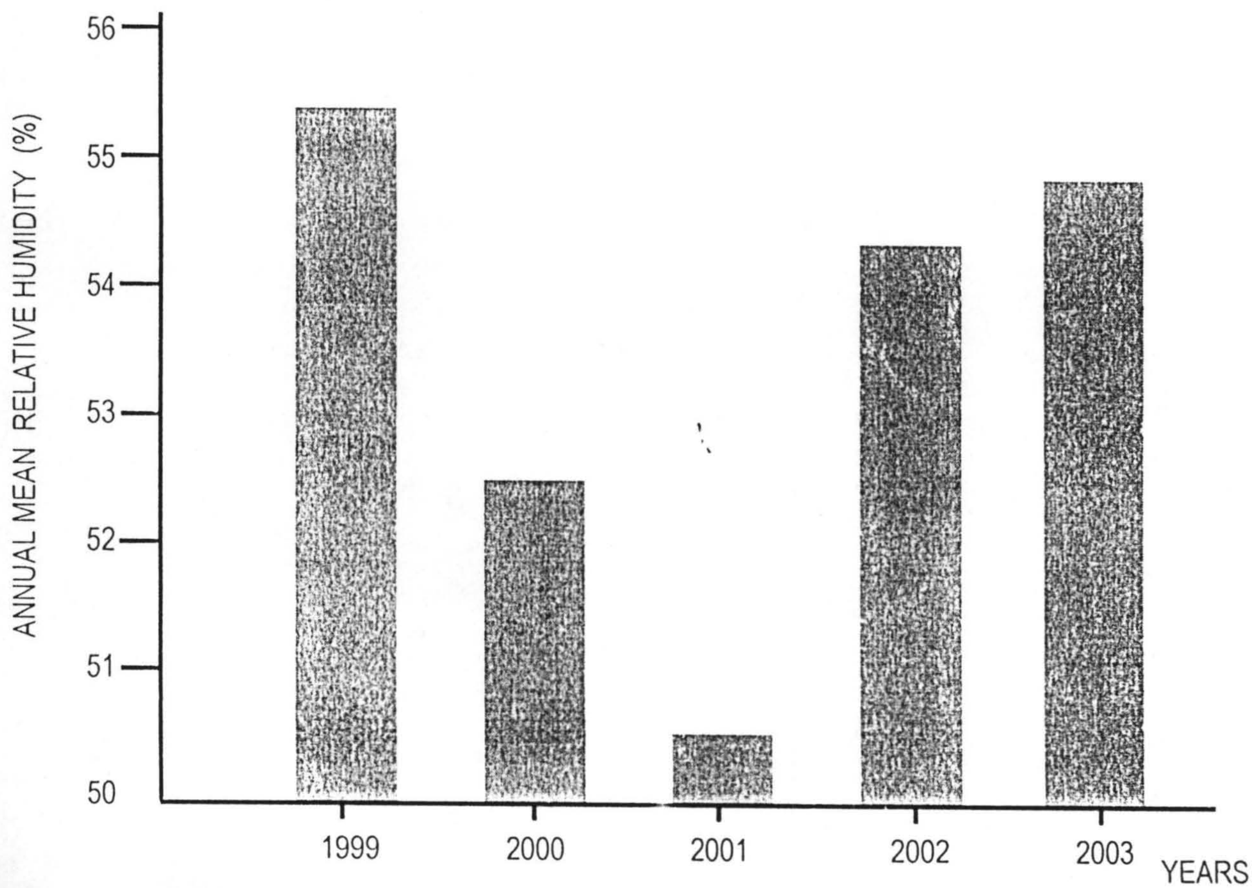
SOURCE: KADUNA METEOROLOGICAL STATION FEDERAL AIRPORT AUTHORITY (2004)

FIG 1.2: ANNUAL TOTAL RAINFALL IN KADUNA METROPOLIS



SOURCE: KADUNA METEOROLOGICAL STATION FEDERAL AIRPORT AUTHORITY (2004)

FIG 1.3: ANNUAL MEAN TEMPERATURE IN KADUNA METROPOLIS



SOURCE: KADUNA METEOROLOGICAL STATION FEDERAL AIRPORT

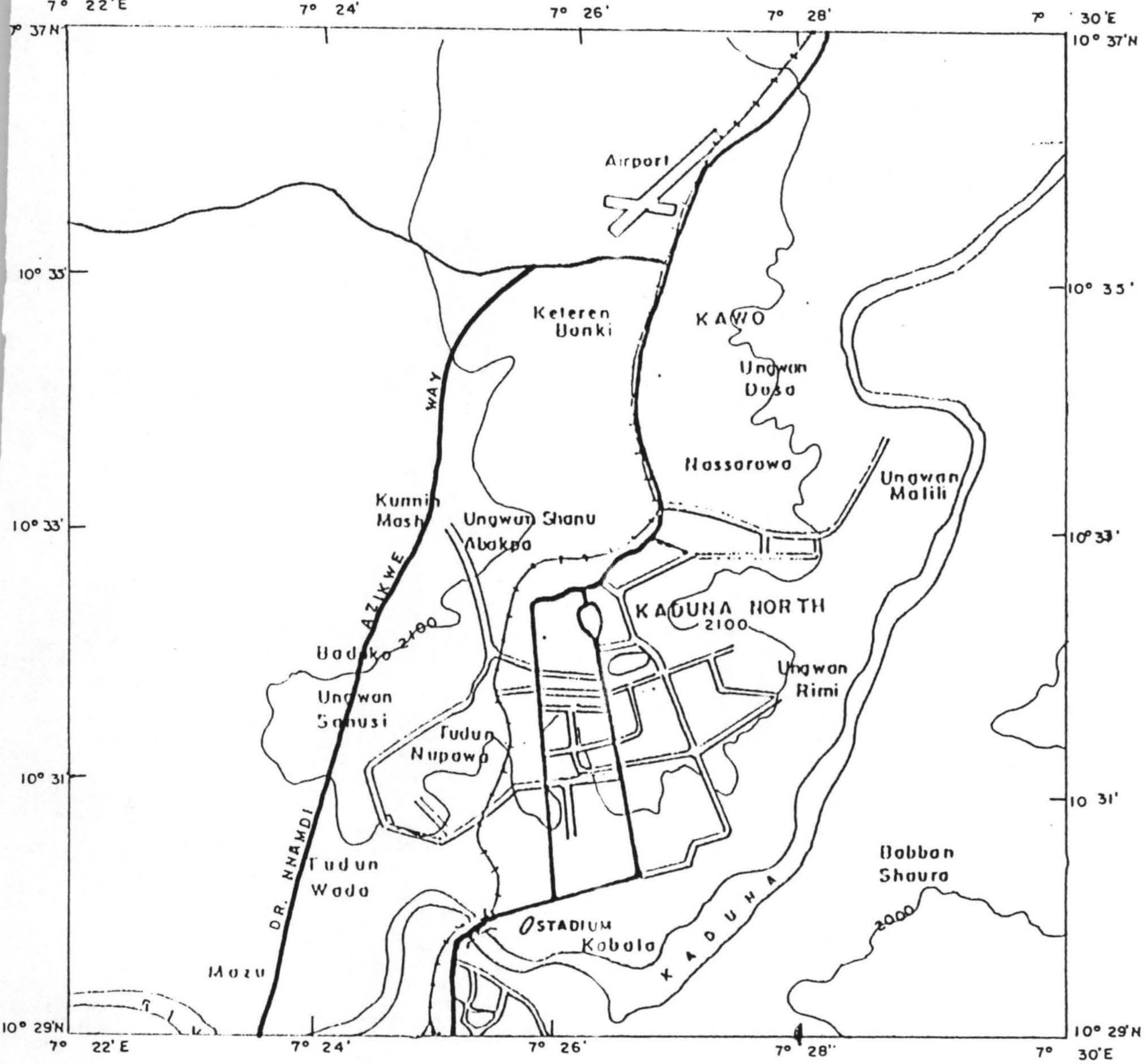
1.5.5 Geology And Relief

The general morphology of the study area (Fig.1.5) consists of an undulating terrain. The bedrock geology is predominantly metamorphic rocks. Deep chemical weathering and fluvial erosion, influenced by the bio-climate nature of the environment, have developed the characteristic high undulating plains with subdued interfluves (Mortimore, 1970). The land shows gentle sloping rock outcrops with relief ranging between 615m and 620m above sea level.

1.5.6 Soils And Vegetation

Generally, the soils and vegetation are typical red-brown to red-yellow tropical ferruginous soils and savannah grassland with scattered trees and woody shrubs.The soils in the upland areas are rich in red clay and sand but poor in organic matter.The soil here is also shallow, of low water retention capacity and are easily erodible.

The flood plains are dominated by gray to dark coloured medium textured loams developed on alluvium. They are relatively deeper and of higher organic matter content.



SOURCE : KADUNA STATE ENVIRONMENTAL PROTECTION AUTHORITY

SCALE :- 1 : 100,000

FIG. 1:5 TOPOGRAPHICAL MAP OF KADUNA METROPOLIS

N

KEY

TOWN CENTRES .... KAWO

ROADS ....

RAILWAY LINE ....

RIVER ....

CONTOUR LINE 2000

1.5.7 Drainage Pattern

River Kaduna is the main river in the town (see Fig.1.6). The river runs from north eastern part, traversing the city center towards the south west outskirt of the town, picking up tributary drainage watercourses. Various minor drainages feed River Kaduna with storm water runoff especially during rainy season.

1.5.8 Landuse

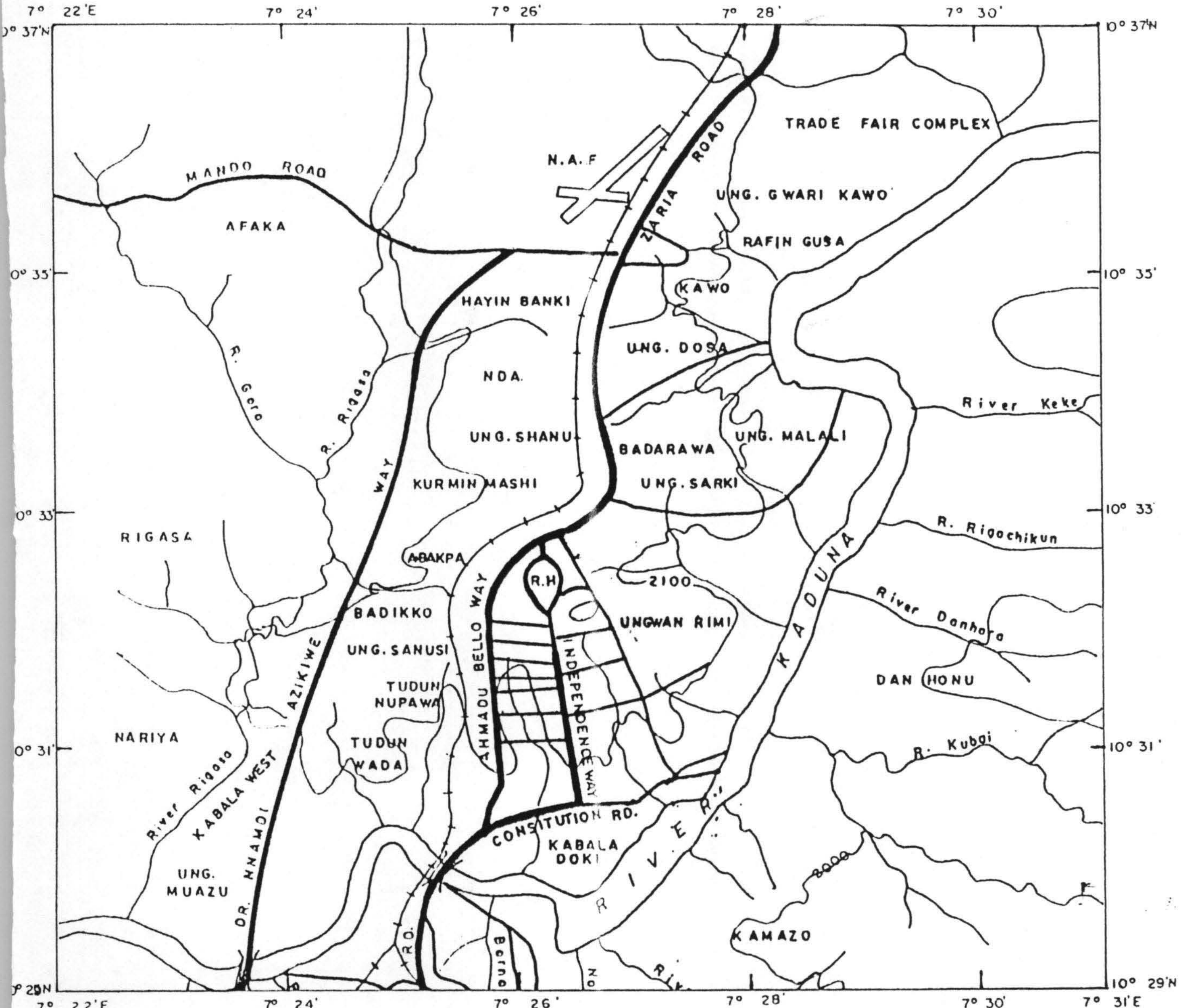
Landuse involves the uses to which land is put into and can be classified into residential, commercial, recreational, institutional, religious and industrial.

1.5.9 Natural Resources

Kaduna State is endowed with a wide range of natural resources which are awaiting full utilization. The natural resources potentials are grouped into agriculture / forestry, livestock and minerals.

1.5.9.1 Agricultural / Forestry

The tropical ferruginous soils on the rolling high plains have been intensively used for cereal cultivation. The not – so- rich soils with good conservation and land management practices are capable of supporting calcium rich grass for livestock feeding. Various root crops such as yam, maize, cereals, cassava and ginger are commonly cultivated. Forest reserves are limited, except in some few riverine areas.



SOURCE: KADUNA STATE ENVIRONMENTAL PROTECTION AUTHORITY

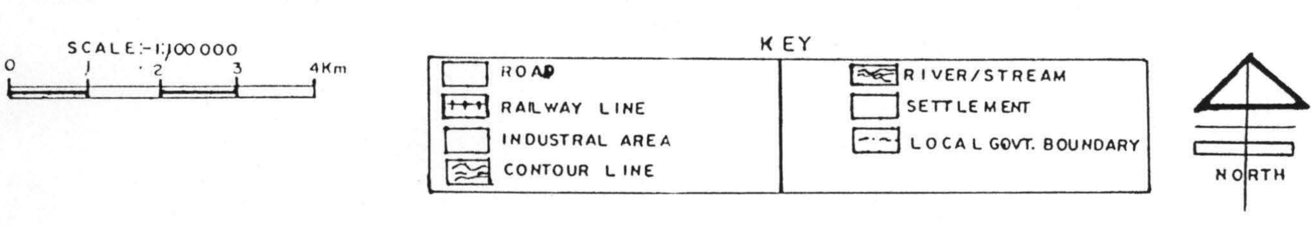


FIG: 1·6 DRAINAGE AND SETTLEMENT IN KADUNA METROPOLIS

1.5.9.2 LIVESTOCK

Livestock resources are still in small scale. Some areas of the state possess development potentials for excellent rangeland to support large scale livestock production. The National Animal Production Research Institute (NAPRI) at Shika, near Zaria in Kaduna State, offers good veterinary technical advice and services.

1.5.9.3 MINERAL

Large quantities of graphite, kyanite and rutile are found in the state. These are good sources of raw materials for pencils, welding electrodes and ceramic industries. Mining of magnetite / hematite are also locally exploited for making local iron implements.

It also has the potential to support small to medium furnace for production of iron billets that can in turn be used in small scale industries. Also, some broad river valleys are rich sources of sand, granite rocks and clay that are exploited for building (Source: Kaduna State Ministry of Commerce, industry and tourism, 1992).

1.6. SCOPE AND LIMITATION

The project was limited to the urban part of Kaduna which has the river Kaduna traversing across the middle of the town (Fig.1.3).

The remotely – sensed data used is the SPOT imagery which served as an input to geographic information system (GIS). Regrettably, the SPOT data used in the analysis does not have a digital elevation model (DEM). A topographical map of this study area was manually digitized to generate the digital elevation model (DEM) of the study area.

CHAPTER TWO

2.0 LITERATURE REVIEW

In recent times, remote sensing and geographic information system have become the major technologies /tools for mapping of flood prone areas. Development in the field of remote sensing has evolved from optical to radar remote sensing, which has provided all weather capacity compared to the optical sensors. Satellite data, provide the best alternative data source for flood modeling.

2.1 Use of optical remote sensing image data for delineating floodable Areas

The landsat multi spectral scanner (MSS) data were used to deal with flood affected areas of IOWA, Arizona and Mississippi River Basin.

In the early 1980s, landsat Thematic Mapper ™ imageries with 30m resolution became the prime source of data for monitoring flood and delineating the boundary of inundation. For obvious reason landsat TM band 4 proves to be very useful in discriminating water from the dry and land surface because it is a near equivalent of MSS band 7 Landsat TM NIR band cannot be used optimally in developed landuse areas such as Downtown commercial or industrial areas. The reason responsible for this is that NIR band reflects very little energy for asphalt areas, appearing black in the imageries.

Wang et al (2002) was able to solve this problem by adding landsat TM band 7 with the NIR band 4 to delineate the inundated areas. In TM band 7 (2.08 – 2.35um) image reflectance from water, paved road surface, rooftops differ significantly. Combined use of band 4 and band 7 image makes it easier to choose the density slice for extracting the flood water. But in some cases a simple density slice or supervised classification is not enough to identify the inundated area accurately.

The concept of SPOT multispectral imageries, were also used for flood delineation with the similar assumption that water has very low reflectance in the near infrared portion of the spectra. SPOT imageries, for example, were used along with a DEM for delineation of monsoon flood in Bangladesh (Brouder, 1994: Oberstadler et al, 1997; Profeti et all, 1997, Sado et al., 1997).

Similarly, it has been discovered that Advanced Very High Resolution Radiometer (AVHRR) data is useful for mapping floods at regional levels. Although AVHRR images are coarse in resolution and frequently contaminated by cloud cover, its merit lies in its high temporal resolution. This advantages makes it possible to monitor the progress of a flood in near real – time.

MSS band 7 (0.8-1.1mm) has been found particularly suitable for distinguishing water or moist soil from dry surface due to strong absorption of water in the near infrared range of the spectrum (Smith, 1997).

Despite the legacy of photo – interpretation, remote sensing data from satellite especially land sat TM and SPOT have become well established as primary source of information in many applications related to natural resources. The inherently digital format of the data, the frequency of the routing coverage of large areas, the lower cost of data and the relative ease with which near–nadir imagery can be geo–referenced. These offer some significant advantages over photographic coverage of the same area at mapping scales of 1: 50,000 or smaller. Although aerial photographs can be digitzed, problems of strong bi–directional reflectance and lens full–off hinder the classification of the resultant imagery.

2.2 Use Of Microwave Remote-Sensing Image Data For Delineating Floodable areas

According to Rango et al (1977), the existence of cloud cover appears as the single most important impediment to capture the progress of floods in bad weather condition. The development of microwave remote sensing, particularly radar imageries solve the problem because radar pulse can penetrate cloud cover. The most recent and common approach to flood management is to use synthetic aperture radar (SAR) imagery and optical remote sensing imagery simultaneously Honda et al (1997). It is worthy to note that apart from the weather capability, SAR imageries possess the most important advantage as its ability to sharply distinguish between land and water.

According to Liu et al (1999), threshold is one of the most frequently used techniques in active remote sensing to segregate flooded areas from non – flooded areas in radar image. The technique involve setting in decibel (DB) a threshold value of radar back scatter and binary algorithm is followed to determine whether a given raster cell is flooded or not radar back scatter is computed as a function of the incidence angle of the sensor and digital number (DN) (Chen et al, 1999).

NICO et al (2000) discussed how change detection can be used as a powerful tool to detect flooded area in SAR imagery. The operation involved acquiring two imageries taken before and after the flood. He explained how coherence and amplitude change detection techniques were widely applied in SAR domain.

ERS –1 SAR (radar) image was acquired and used for delineation of the submerged area during the Herault flood in France in January 1966. The flooded submerged area runs from the Orb valley all the way down to the Mediterranean sea.

Baba (1998) clearly demonstrated how Landsat data could be used to delineate the flood plains of the Sokoto – Rima river Oyotem in northwestern Nigeria.

Landsat MSS imagery was used successfully by Elukpo (1998) to carry out the landuse configuration study of Goronyo, Sokoto state.

Olaneale (1998) used aerial photograph and Landsat MSS image data to determine the cause of river flooding of river Osun in Ikere – Ekiti, Ekiti state, Nigeria. He discovered that the increased flooding in recent times in the study area is as a result of the expansion in built – up areas (especially towards the floodplains), the extension of agricultural practise at the upper course of the river, deforestation and the presence of large barren land.

SPOT XS and meterorological data were also used as assessing seasonal change in water volume in Kainji Lake, Nigeria (Owolabi, 2000).

2.3 Use Of Geographical Information System (GIS) To Delineate Floodable Areas

According to Coppock (1995), geographic information system (GIS) has a great role to play in management of natural hazards. Natural hazard like flooding can manifest in different forms and dimensions. The main advantage of using GIS for flood management (Clark et al 1998) is " that it not only generate a visualization of flooding but also created a potential to further analyze this product to estimate probably damage due to flood".

Geographical information system deals with spatial data which are always geo-referenced. The referencing of data to a location on the ground (geo – referenced) is a fundamental requirement in GIS. All projections are made to define a precise location using latitude / longitude (geographic) and geoid system GIS are based on real world coordinates. This gives a unique way to place widely dispersed features in context relative to one another (topology),(Okonrokwo, 1994).

Spatial data is conceptualized as view of reality. According to Kufoniyi (1998),a spatial data is the mental abstraction of the reality for a particular application or group of applications. On the other hand, Raper (1993) stated that reality can be visualized as points, lines, polygons (area) and volume ie O-D,1-D,2-D,3-D phenomena respectively in GIS. Rolf et al (1999) described spatial data model as a high – level language that allows us to describe (model, specify) a number of real world phenomena; some of which have a spatial characteristics and their relationships. This description is the formal abstraction of a chosen set of real world phenomena. Besides, identifying the conceptual structures as the static part of these phenomena, a complete spatial data model also allows the description of the behaviors of the observed phenomena (flooding) to an extent. This complete structure and behaviour called conceptual is devoid of implementation considerations.

GIS was applied in the preparation of a GIS database for erosion assessment in the upper Ewaso Ngiro north Basin, Kenya (Mati et al 1989). The database was also required for resource monitoring (soils, topography, wildlife, rainfall) and for planning and management of projects such as soil conservation, water supply, irrigation and drainage. The methodology used to capture data was through digitizing of the thematic maps (rainfall, agro climatic zone map, soils land use/ land cover and drainage). The data collected were entered into relational database management system. A PC Arc/info version 3.1.4 and arc view version 3.0 software were used to manage the database which provide a useful tool for soil erosion assessment in the upper Ewaso Ngiro Basin in Kenya.

GIS was also used in handling information gathered by the Canada Land Inventory (Tomlinson et al, 1976). The project was put in place to obtain thematic coverages such as watersheds and shorelines. Source data were collected and mapped in polygon (i.e vector) form and imputed either by scanner or manual digitizing. The data model used was relational data model implemented by Arc/ Info software.

The use of GIS and satellite remote sensing to map woody vegetation was also demonstrated in Kazgrail area of Sudan. The project was put in place to rehabilitate the acacia Senegal lands known as the "GUM BELT". The methodology used was to capture data with the use of remote sensing. The sample site coordinates were established using GPS receivers. The data collected were entered into relational database management system with program to summarize the observations into table. A database IV and Atlas graphics were used to manage the database while the map of the results were plotted using boundary files created in an Arc/ Info system (Forest National Corporation of Sudan,1991).

From the aforegoing, it is clear that the capacity of geographic information system (GIS) to effectively handle large spatial datasets makes it a potential powerful tool for efficient environmental monitoring activities such as flooding where data sets are easily transformed into useful information for decision makers (Barandela,1997).

The reduction of disaster due to coastal flooding, related to cyclones (or westerly storms) is concentrated on early warning based on monitoring cyclone tracks using space borne, air borne, and ground radar system (Verstappen, 1999).

Geo-spatial information system is fed and complemented by remotely sensed data to bring about emergency response for coastal flood assessment.

2.4 Ecological Role of Flood.

According to United States Geological survey (USGS) information and assessment technical report (1999), flood has been an agent of disturbance from time immemorial. Floods have occurred long before the advent of humans on earth. It has been shaping landscape structure, pattern and ultimately the species composition of ecosystem. The ecological role of flood has been that it influences several factors such as plant community development, soil nutrient availability and biological diversity. The report has it that flood can cause tremendous advert impacts on the environment and human society (USGS, 1999).

2.5 Changes Affecting The Role Of Flood As An Ecological Tool.

In very recent times changes have been occurring globally. These changes are affecting the role of flood in ecosystems. Writing on these change Johanna and Landsberg (1997) are of the view that two physical changes namely: global increases in population and climate change since the last glaciations have produced impacts affecting the evolution of flood regimes.

Maina (1998) discussed the rural – urban migration of people into the metropolis in quest of job opportunities and livelihood has culminated in the demand for more housing accommodation and leasing of plot of land by the land owners. As people became desperate to purchase land to build houses, so were the plots of land sold indiscriminately with little or no planning. The result was that residential house were built close together without adequate space to streets and drainage system. The deplorable environment in which large proportion of residents live in greatly exacerbated by lack of proper drainage system and during the raining season (June – October) of each year several areas are flooded. At this time many households are either forced to live in damp water logged buildings and wade knee – deep in floodwater.

According to Micah and Musa (1998), another factor that creates seasonal floods is the population growth. The rapid rate of population growth has resulted in poor urban planning, especially in its land used system. Poorly maintained winding street patterns of the area do not give room for efficient evacuation of solid wastes. Not only are the solid waste not evacuated, there is total lack refuse collection centers. This has led to the indiscriminate dumping of solid waste along the street sides, in depression, dunghills and drainage channels. Besides, the organic poisonous stinking odour that emanates from them, thus, polluting the entire environment. The waste materials reduce the capacity of the few drainage channels available to contain floodwater. It also disrupts the free flow of surface water causing flood. Table 2.1 shows the breakdown of the type of solid waste in the study area.

Table 2.1 Composition of Wastes

COMPONENT	WEIGHT IN KG.	PERCENTAGE %
Animal Faeces	151	50.7
Plastics /Papers	60	20.1
Garden Waste	41	13.8
Textile	20	6.7
Ash Dust	12	4.0
Garbage	9	3.0
Others	7	2.3
Total	298	100

Source: Adapted from Musa (1998). Geography and Nigerian environmental: A book of reading.

The New Nigeria newspapers of 5th September 2003, reported that as a result of the flood in Kaduna, resident in the metropolis were said to have suffered from water borne diseases such as cholera, dysentery, gastrointestinal diseases etc.

The flood incidence that occurred in Kano in 1998 was traced to the fragrant disregard to town planning regulations and poor refuse disposal system. The resulted flood disaster ravaged lives and properties in Kuntawa, Mandanari, Sheka and Geza wards. Other places include Birni Iya, Gwale, Dala, Fagge and Wudiluwa Municipal; also are Dala, Fagge and Tarami local Government areas in Kano (New Nigeria, August 19,1998). Similarly, the dumping of wastes in channels and un cleared waste on the streets was association with the ill-fated 1994 Maiduguri flood disaster (kodiya, 1996).

Knighton (1993) made it known that socio economic and anthropogenic activities have been found to induce or intensify flood condition in our environment. Through land use, the basins of streams traversing cities are now made impervious by the housing orientation and roofing system.

CHAPTER THREE

3.0 DATA AND COMPUTATIONAL TECHNIQUE

This chapter looks at the methodology used in achieving the objectives of the study.

3.1 Description of data

The data for this project were acquired through both primary and secondary sources.

3.1.1 Primary Source of Data

(a) The questionnaires administered Appendix I helped to show the flood limits attained by the flood.

(b) Field survey was carried out using GPS to obtain coordinates (x, y, z) of flood limits.

3.1.2 Secondary Source of Data

a The topographic map of the study area at scale 1:25,000 sheet.

b SPOT [system pour observation de la Terre] 3 multi-spectral [X5] digital satellite image data of 3rd December 1994.

A summary of the data sources and their characteristics are shown below.

TABLE 3.1 DATA SOURCES AND THEIR CHARACTERISTICS

Data Type	Date	Scale	Identification	Acquisition source
SPOT [XS] image	3rd Dec. 1994	1:50,000	Appendix III	Centre National d' Etudes spectiades [CES] Toilouse France
Map of Nigeria	Year 2001	1:100,000	Fig. 1.1	Federal survey Lagos, Nigeria
Map of Kaduna State	Year 1994	1:50,000	Fig. 1.2	Kaduna State Survey & Country Planning, Kaduna
Map of Kaduna	Year 1994	1:5,000	Fig. 1.2	Kaduna State Survey & Country Planning, Kaduna
Topographic map	Year 1991	1:25,000	Sheet -	Fed. Survey Lagos, Nigeria

Source: Author's work (2005).

3.2 systems Selection

The various systems involved hardware and software.

3.2.1 Hardware

The hardware and their features used for this project include:-

- Pentium based PC
- Ram size 256 MB
- Storage capacity 60 GB HDD

- Clock speed 100 MHZ
- Video driver SVGA [super video graphic adapter]
- Disk operating system [DOS] window, 98, 2000
- Monitor 14"
- Backing up HDDT, CD- Rom
- Printer A3 Laser printer
- Calcomp AO Digitizer set with cordless (see fig,3.3)
- Scanner (see fig.3.4)
- 3 Key button mouse

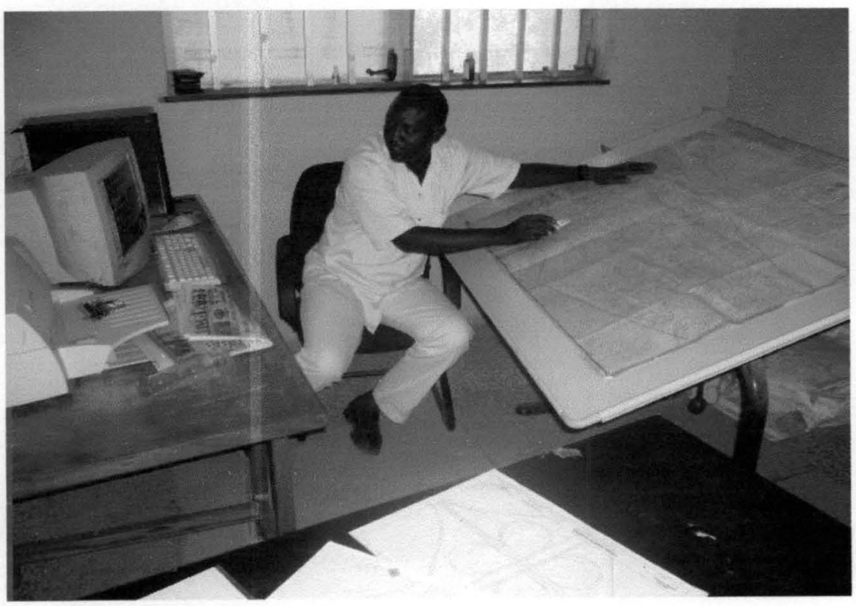


Figure 3.1 A0 CALCOM DIGITIZER TABLET (one of the data Inputting GIS Hardware). Source: Author's work (2005).

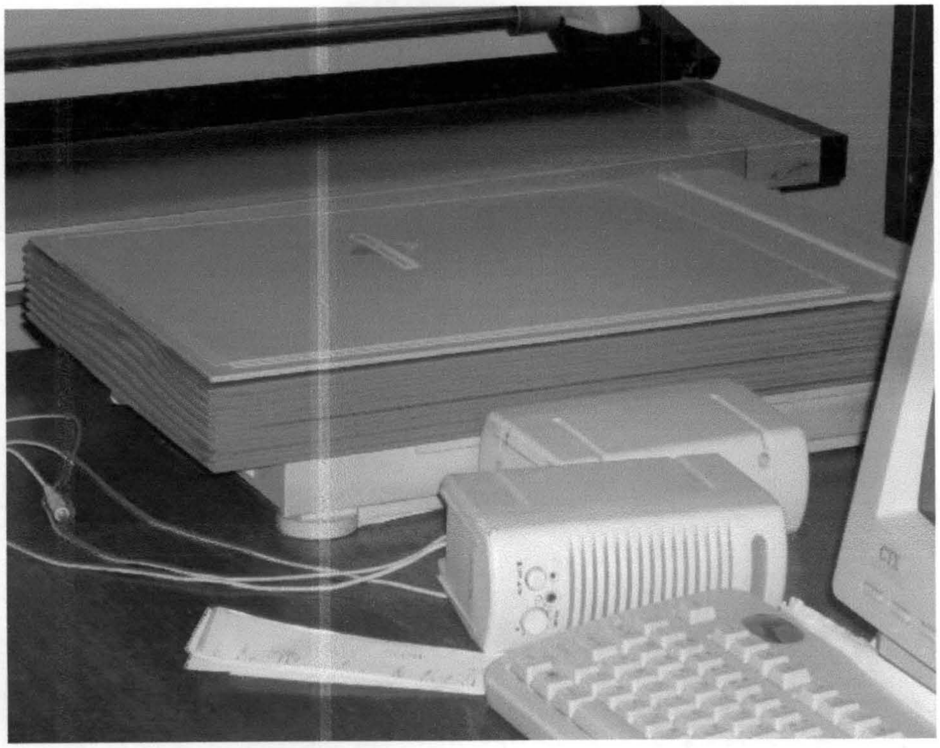


Figure 3.2 A3 SCANNER (one of the inputting GIS Hardware).

Source: Author's work (2005).

3..2.2 Software

Three kinds of softwares were used in this project. These are:-

a. ERDAS [Earth resources data acquisition] system imagine. It is a digital image processing software which allows for sub-pixel analysis to deconvolve the spectral signature of a pixel into its constituent spectral components which represent multiple objects within the pixels.

b. ARCVIEW GIS :- It is used as a mapping and GIS tool that selects and displays different combination. [Map composition and overlay of information].

c. ARC/INFO- is a vector-based GIS software for storing, analyzing, managing and displaying topologically structured geographic data. It was used for the editing.

3.3 Computational Technique

A pre-processed image (Appendix II) was used for this study which is free of inherent errors or distortions.

3.4 Image Interpretation

The scenes covering the study area were selected using the index specified by the paths and rows as delineated by the coordinate of the area. Two scenes covering the study are were imported into Arcview GIS software. Mosaicing of the two scenes was carried out to obtain a continuous image over the study area. The image was geo-referenced to the Universal Transverese Mercator (UTM) projection co-ordinates (X,Y) of an existing topographical the study area.

The co-ordinates of the study area were defined in latitude and longitude and converted to rectangular coordinates. A box defining the area was created. Using the box, the exact extent of the study area was clipped from the imagery. On-screen visual interpretation was performed to obtain the features such as water bodies, roads, rivers/streams, buildings or settlements, vegetation, railway line using an interpretation key (table 3.2).

TABLE 3.2 Interpretation Key For Spot X S Band

S/No	Features	Tone/Colour	Texture	Size	Shape	Pattern
1.	Water bodies	Dark grey	Fine	Variabl e	Round or variable	[rregular or dispersed.
2.	Roads	"	F[ne	Variabl e or uniform	Straight with sharp bends.	Linear
3.	Rivers/streams	"	Fine	Variabl e	Variable	Linear
4.	Residential	"	Medium	Mediu m	F[ne	Rectangle
5.	Vegetation	Reddish	Medium	Variabl e or Fixed	Variable or fixed.	Irregular or dispersed.
6.	Railway lines	Dark grey	Medium	Fixed	Long & straight	Linear.

Source: Author 's work (2005).

Upon interpretation, three layers of detail, features were used in the modeling of the remotely-sensed data. These are settlements, streams/river and roads. A separate layer, the digital terrain model [DTM], was generated by digitizing points along contours from an existing map of the study area (of 1:25,000 scale). All these were combined together to form the composite map [model] which was buffered to provide a more appearing perspective view of the study area that are liable to flooding.

3.5 Database Design

For a proper implementation of a GIS, the design of the spatial database, which is the heart of the GIS, must be handled carefully. The database design is the process by which the real world entities and their interrelationships are analyzed and modeled in such a way that maximum benefits are derived while utilizing a minimum amount of data [Kufoniyi, 1998]. The design phase (Fig.3.3) was treated under four recognized and interrelated stages viz: the view of reality, conceptual design, logical design and physical design.

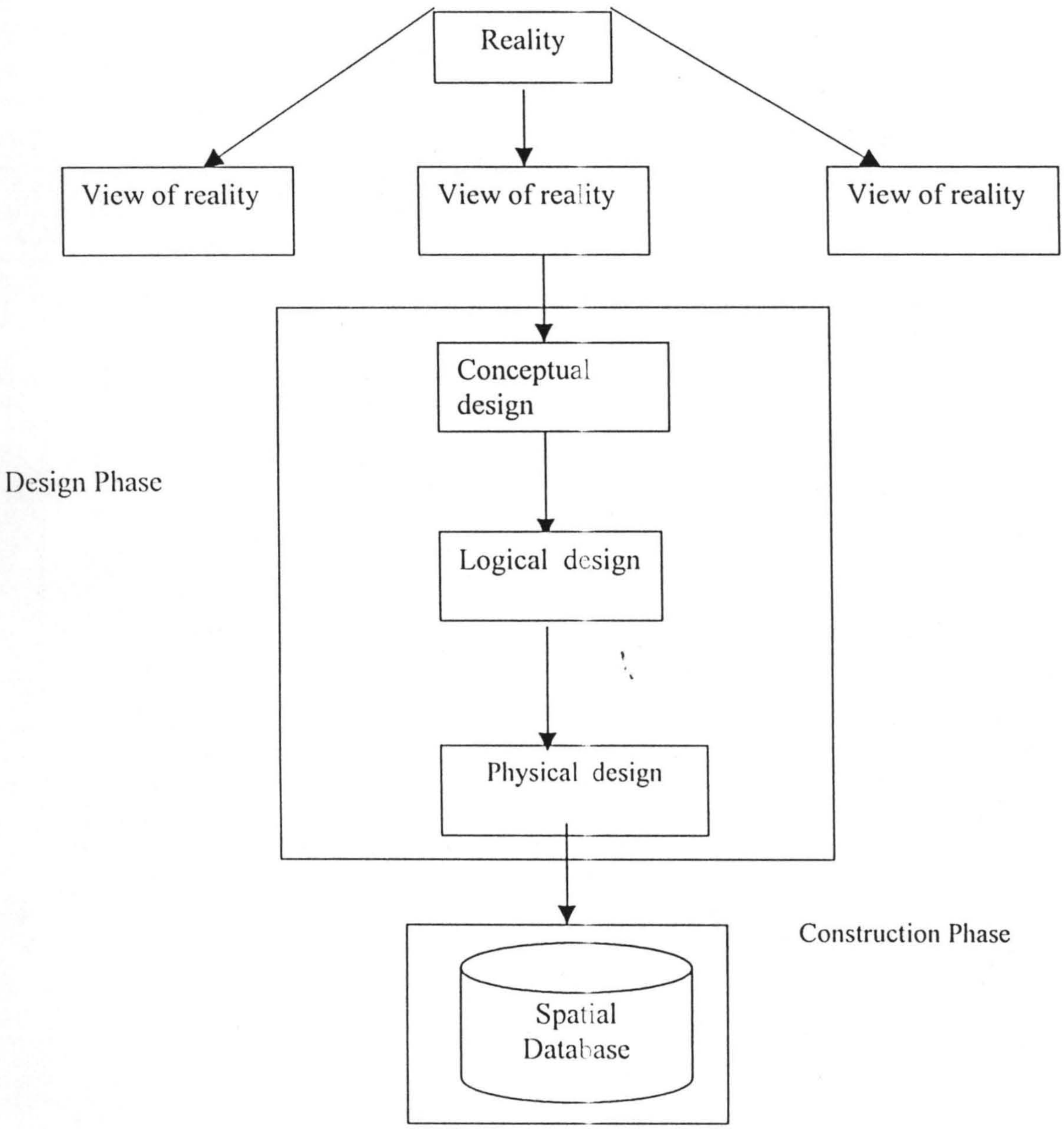


Fig. 3:3 Design and construction phase of a spatial database [Adopted after Kufoniyi, [1998].

3.5.1 View of Reality

This has to do with the mental abstraction of reality i.e. entities present in the study area for a particular application or group of applications. In the study area, there are point objects e.g. electric pole, linear objects e.g. stream and polygon objects e.g. buildings.

3.5.2 Conceptual Design

At this stage, decision was made to represent the view of reality in a simplified manner but still satisfy the information requirement. There are three types of representation scheme namely: vector, Tessellation and Object-Oriented data models. For this project, both vector and tessellation data models were adopted.

Vector Data Model: Here terrain features were represented as :-

(ι) Point object [O-D]: i.e. an object without length or volume represented by node. It has X, Y coordinates. e.g station point.

(ιι) Linear object [1-D]: An object with length that has no height. It has X,Y coordinates. e.g streams/rivers.

(ιιι) Polygon object [2-D]: This is a close loop without height represented by X, Y coordinates. e.g road.

(ιϖ) Body object [3-D]: This is an area object with height represented by X, Y, Z coordinates. e.g buildings. Figure 3.2 gives entities and their relationships.

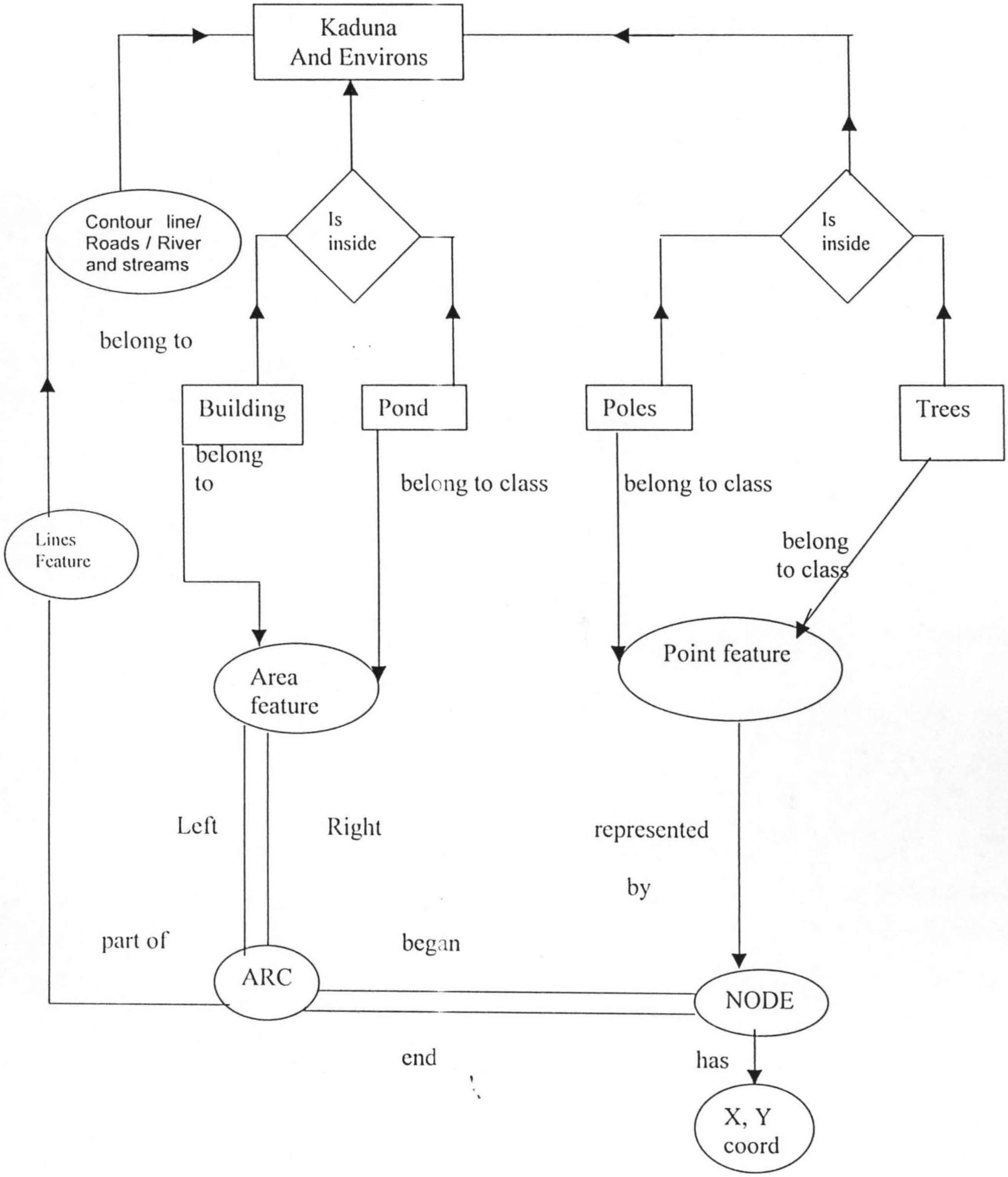


Fig. 3.4 Entity relation diagram showing Topographical Base information system. (Adopted from Kufoniyi, 1997).

Vector data model may be unstructured [spaghetti format] or structured [e.g. topologic]. The latter was adopted for this project.

Tessellation: Where the geographic space is partitioned into regular [e.g. Raster] or irregular e.g. Triangulated Irregular Network, TIN] cells and each cell is characterized by: (i) The area it covers, and (ii) One or several values describing non-spatial properties of the cell. Raster data model was adopted for this project; the vector data were rasterized so as to carry out some analysis in the next chapter.

3.5.3 Logical Design

Logical design, which is the same as data structure has to do with the way the data are represented in the computer system. For this project, relational data structure was adopted. The conceptual data model was translated into a relational data structure. Below are examples of some tables [relations] derived from the figure.:

Polygon object [Polyid, type name, use, area,...]

Polygon object [Pid, Polyid, name,....]

Line object [Lid, type, name...]

Where "Polygon object", e.g. building is one of the entities (relations)

"Polyid" is polygon identifier

"Type" is the type of polygon object

"Use" is the use to which the polygon objects is put

"Area" is the area of the polygon object

NOTE: The ARC and NODE were created automatically by the software during digitizing.

3.5.4 Physical Design

This is the representation of the data structure in the format of the implementation software. In this project, the graphic data were presented in digital form through manual digitizing of the topographical map of the study area. The line features were digitized as segment map, area or polygon objects as segment map and the point objects as point map in different layers. For improved accuracy of the project, the digitized features were edited for self-overlap, dead end, intersection and code consistency. Arc/Info was the software used for data capture and editing. Arcview was used for the presentation.

3.6 TOPOGRAPHIC DATABASE CREATION

After designing data structure and it was ascertained that the necessary hardware and software were available, the next thing that was done was the input of spatial and attribute data into the computer via digitizer (calcomp AO) and keyboard and by this the database was being created (fig. 3.3). Data types were input in different layers and overlaid. The attribute data were linked to the spatial data via their domain. Before the input of data proper, map referencing was carried out.

3.6.1 Map Referencing

The coordinates of the base map were referenced to that of the digitizer using minimum of four control points (A,B,C,D) and the corresponding map coordinates. A coordinate system for Kaduna was first established by double- clicking the New Crdsys (new coordinate system) in the operations-list of the software main window. The projection used for the coordinate system was UTM (Universal Traverse Mercator), Clarke 1886 was the ellipsoid and Minna datum with Nigeria as area was selected, also UTM zone 32 used.

The minimum and maximum X,Y coordinated are:

Min. X: 325789.00

Min. Y: 1164451.00

Max X: 326880.00

Max Y: 1166024.00

The referencing was done after the coordinates system has been established. The steps taken are outlined below:

(ι) Base map positioned on the center of digitizer and fasten with tape.

(ιι) Digitizer selected from option menu of the main window.

(ιιι) Choose Map Referencing from the list box coordinate system.

(ιϖ) Dialog box opened.

(ϖ) Kaduna was selected from the list box coordinate system.

(ϖι) Clicked OK button.

(ϖιι) Dialog box and command box opened.

(ϖιιι) Positioned digitizer cursor at point A of the map and pressed OK Button.

(ιξ) Entered Min X, Min Y.

(ξ) At point B.

(ξι) Entered Max X, Max Y.

(ξιι) At point D.

(ξιιι) Entered Min X, Max Y.

Affined transformation was used since both coordinate system used are metric. The sigma (standard deviation) value was 0.4 and since this was less than 1, the Ok button was clicked to accept the referencing.

3.6.2 Digitizing Point Map

A point map called poles was chosen out of all point maps created Sto demonstrate how point maps were input into the computer:

NOTE: The base map was still on the digitizer.

Double clicked New pnt Map in the operations-list"'.

Dialog box opened

Typed poles in the map name text box

Typed for description: Point indicating Electric Poles

Selected coordinate system Kaduna.

Typed Posts in the text box Domain name in the domain dialog box.

Option Identifier selected.

NOTE: The domain types identifier was selected because each point in the map was uniquely identified.

Click Ok button

Domain Editor opened; default was accepted

Point Map dialog box opened

Click opened

Display Options point dialog box opened

Click Ok button

Point Editor and Point Editor command box opened.

In the editor's environment, the points were digitized.

3.6.3 Digitizing Segment Map

The same steps as in point map were taken except that the create segment map was chosen instead of New point Map and option Class was selected as domain type instead of identifier. For example, for segment map Building, coordinate systems was Kaduna, domain was build and for domain type, option was selected.

3.6.4 Digitizing Contour Lines

In 3.5.3, segment map with a class domain was digitized. Here digitizing of segment map with value domain was height as the value. See below in the steps taken:

Double-clicked New see Map in the operation-list

Dialog box opened

Typed Contour for the map name

Selected coordinates system Kaduna

Selected domain value

Typed 180 and 200 in the range text boxes and 0.1 in the text box precision.

Clicked Ok button

Segment editor and Add segments command box opened

Selected insert code from edit menu

Digitized the contour line.

NOTE: All the contour lines were digitized after inserting there values. After digitizing code consistency was checked. In addition, pseudo representative was selected, after this, map window closed.

3.6.5 Creating Attribute Table

The tables were created using the software and the values were entered manually from the keyboard. See below for an example:

- Double-clicked New Table in the operations-list
- Dialog box opened
- Typed building in the text box table name
- Description: Information related to building in Kaduna
- Domain; Build
- Click Ok button
- Table window opened
- Selected Add column command from the columns menu
- Dialog box opened
- Typed "TYPE" in the column name text box
- Domain: build
- Option: Class
- Description: Types of building
- Clicked Ok button
- Domain Editor opened. From the Edit menu Add item command was selected.
- Dialog box opened.

- Class name COMPLETE, INCOMPLETE and OPEN SPACE were entered.

Appropriate class was selected from each of the building. To create other columns, the same steps were followed.

3.6.6 GPS [Global Positioning System]

The global positioning system is an extra terrestrial positioning system with the capability of obtaining the horizontal and vertical coordinates of a point simultaneously in ϕ , λ and h or x, y, Z coordinates. Hand-held GPS was used to obtain the maximum flood heights of designated points within the study area.

3.7 Use Of Global Positioning System Heights [Buffer Creation]

Using the global position system [GPS], maximum flood heights were obtained on designated points within the study area using the responses received from the questionnaires administered as shown in questionnaire in appendix I¢. These heights served as the upper limit maximum water level often reached by flood. The stretch range was chosen for buffer creation as shown in fig. 4.3.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION OF RESULTS

4.1 Data Analysis and Result Interpretation

The main aim of this project work is to produce a model that would map areas along the inhabited plain

of River Kaduna, which may become liable to flood disasters, using remotely –sensed data and geographic information system (GIS). In achieving this feat, the objectives set out were to analyse the acquired spot multispectral (XS) image data to provide useful information such as settlements, drainages and road to be incorporated into a GIS.

The resultant output map would be displayed in 3 dimension (3-D), using a digital terrain model (DTM) generated from topographical map encompassed with a buffer zone established as a result of responses obtained from the administered questionnaires.

4.2. Spot XS Satellite Data Image Enhancement and Interpretation

Data image enhancement operation was employed to modify in a useful way or improve the pictorial quality of the image to obtain useful and necessary information of the features within the study area. Spatial enhancement (image filtering) and spectral (radiometric stretching of pixels) techniques were used using ERDAS software. The colour composite of the 3 bands of the SPOT image data was produced.

River Kaduna has a blue colouration and red coloration on its immediate banks. This means that there was strong reflection of band 1 by the river and bands 2 and 3 energies were absorbed at the banks. These spatial appearances are shown in Appendix II.

4.3 Methods Of Data Analysis

The SPOT XS imagery used allows spectral enhancement performed on individual bands selected in which water has a specific reflectance that does not spectrally overlap with other cover classes. Fig 4.1 illustrates this. The image was interpreted with the aid of elements of interpretation keys such as tone/colour. Texture, structure/pattern, size, shape, location and association in the visual analysis of data (Table 3.2).

The use of the multi-spectral [SPOT XS] imagery with its additive colour for easy visualization has provided a non-comparable result for easy interpretation and analysis.The features and objects such as water body, drainages, vegetation, railway lines and roads on images were clearly identified, classified and recognized within the study area.

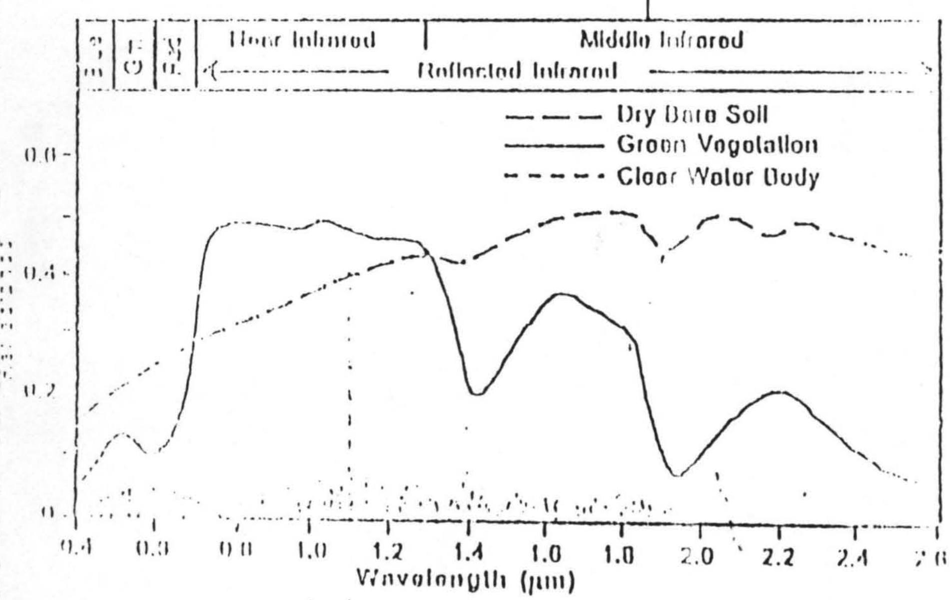
Through the on-screen visual interpretation of the imagery, three distinct layers of details or features were obtained. With the rest data used in modeling of the flood prone areas of the study areas. The layers are settlements, streams/river [drainage's] and roads. These are shown in Figures 4.2 to 4.5.

A composite map displaying all the features in the spatial database created is shown in figure 4.6.

4.4 Map Composition And Overlay Of Information To Obtain A Model Of Flood Prone Areas.

Once a spatial database is created, GIS technology permits the display of graphics by theme in line with the focus at any point in time. An important aspect of a GIS technology is the ability to carry out spatial query on a database. The query retrieves already stored information in the user defined format.

Layers containing information settlements, roads, and streams were overlaid accordingly on the buffer zone already created. ARC/View GIS software was used for the editing, map composition and overlay of information to obtain a model of flood prone areas along the inhabited plain of River Kaduna within the study area.



Source: Adapted from Smith (2000a)

Fig. 4.1 Spectral Reflectance of Vegetation, Soil and Water.

KADUNA METROPOLIS

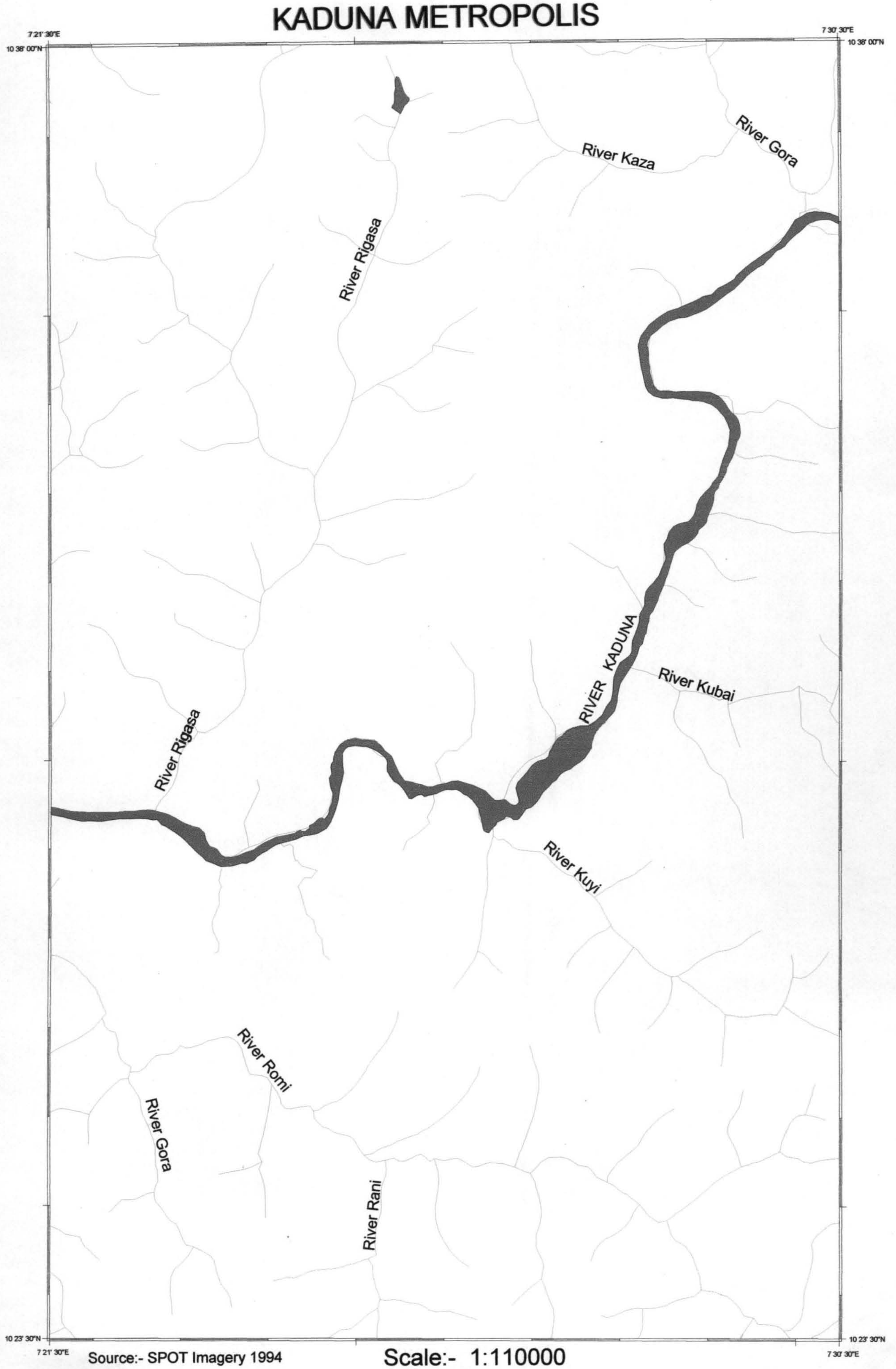
Source:- SPOT Imagery 1994

Scale:- 1:110000

LEGEND

Built-up Area

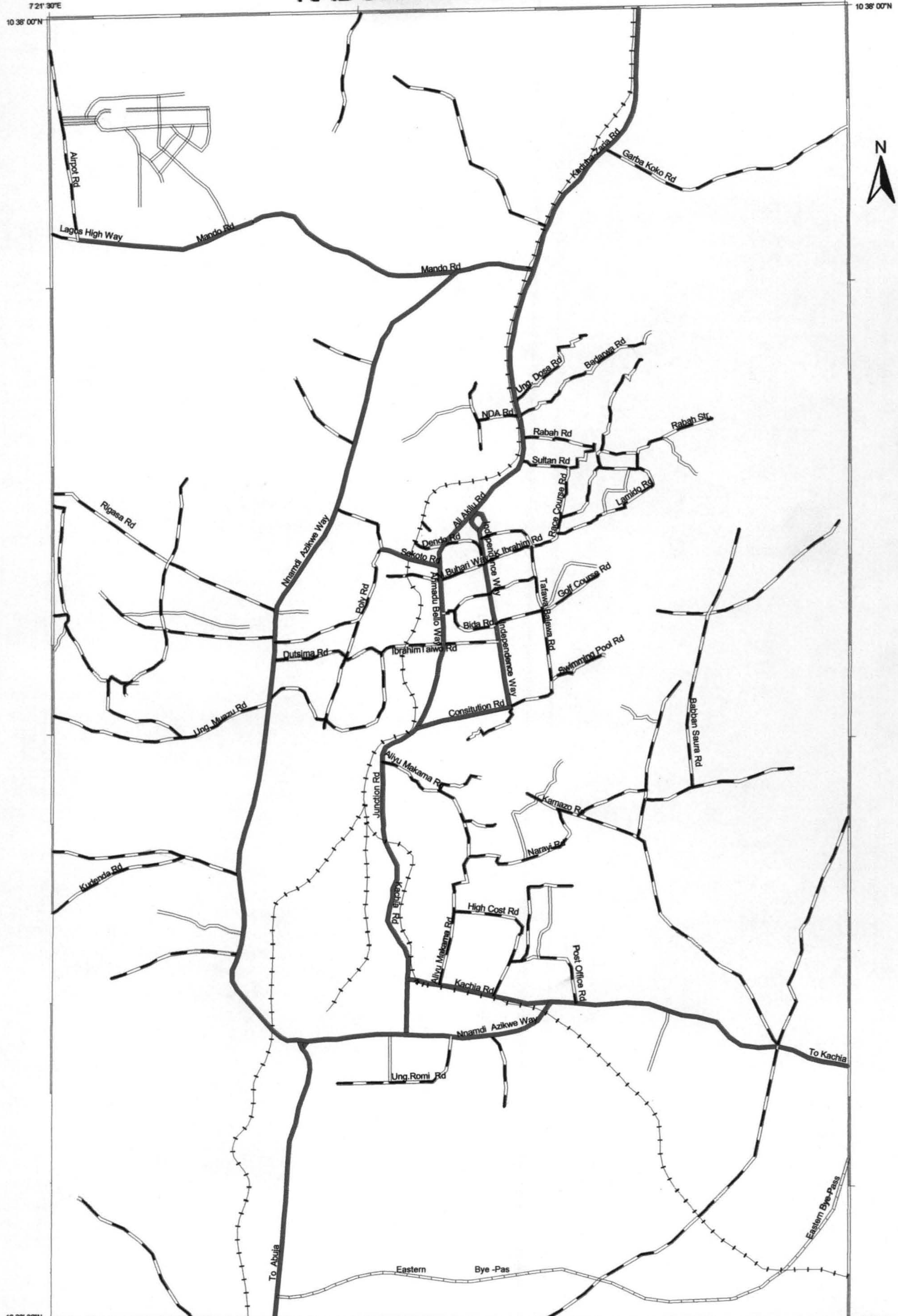
Fig 4.2 Vector Layer Showing Built-up Area



LEGEND
River

Fig 4.3 Vector Layer Showing Rivers and Streams

KADUNA METROPOLIS



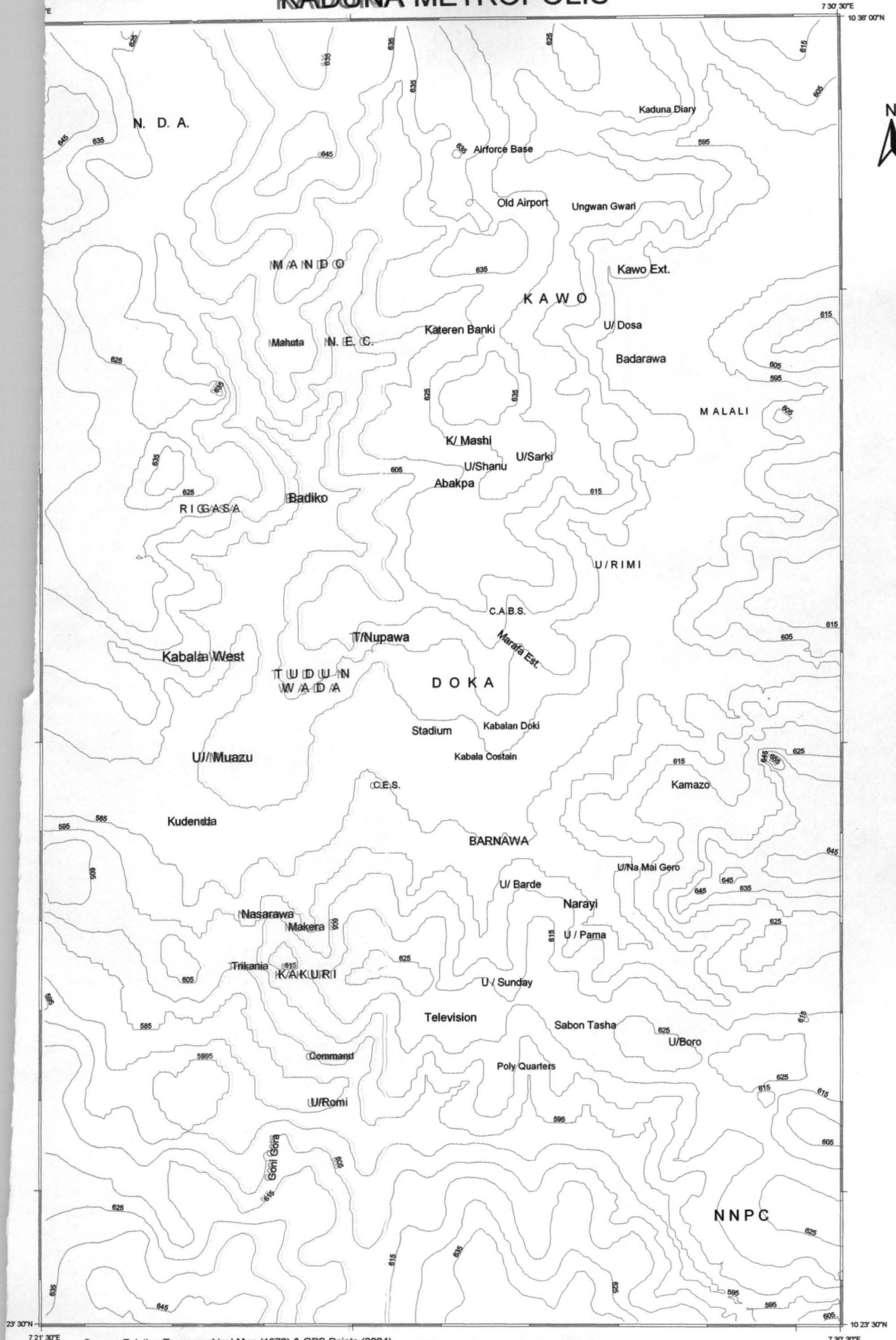
Source: SPOT Imagery 1994

Scale:- 1:110000

LEGEND
- Rail Line
- Dua-Cariage Way
- Major Road
- Undercostruction

Fig. 4.4 Vector Layer Showing Road Network

KADUNA METROPOLIS



Source: Existing Topographical Map (1972) & GPS Points (2004)

Scale:- 1:110000

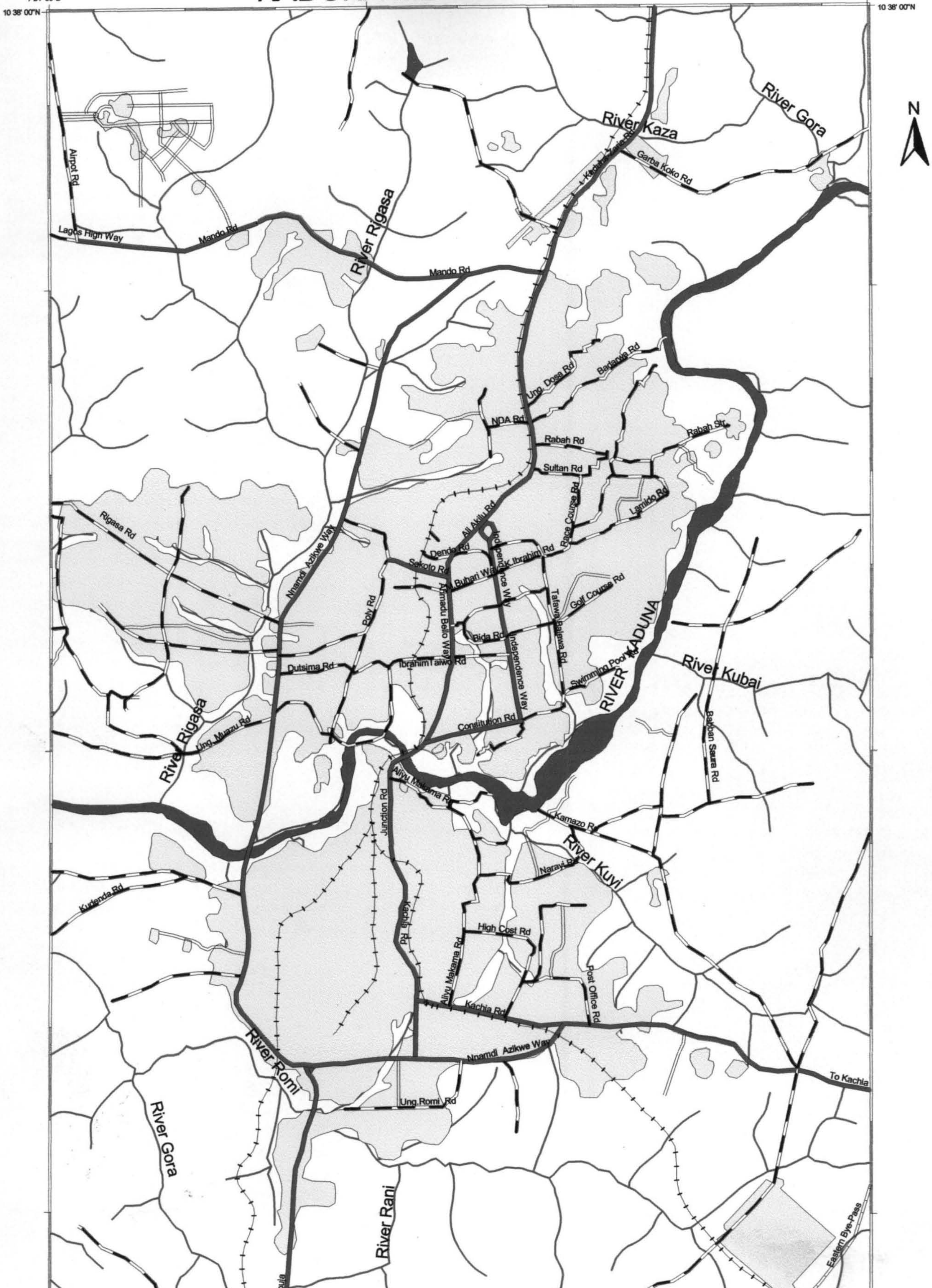
Contour Interval = 10m

LEGEND

Contour Line

Showing Contours Lines

KADUNA METROPOLIS



Source: Adapted from SPOT (XS) image (1994).

Scale:- 1:110000

LEGEND
- Rail line
- Dual carriage way
- Main road
- Other roads
- Road underconstruction
- Built-up area

Fig. 4.6 Composite Map of Kaduna Metropolis

4.5 Settlement (Built-Up) Data Analysis And Interpretation

The built-up areas or settlement data displayed a coloration of reddish which indicates a strong reflectance in the near – infrared energy band (band 1 of the colour composite). The sole aim of this layer is to display the settlements and overlay them on a buffered model to show settlements that are lying in the flood-prone areas or flood risk zone to serve as an early warning system to the inhabitants in the study area. Results of this assessment is shown in figure 4.7.

4.6 Digital Elevation Model, Drainage Pattern Analysis And Interpretation.

Figure 4.8 shows the Digital elevation model with the drainage channels of River Kaduna as the main drainage (appearing with blue coloration). This shows the drainage channels in low elevation channels relative to other areas away from the drains. The contrast in coloration and pattern defined the flood –prone areas.

The resulting image proved to be a useful instrument for the modeling of flood-prone as along the inhabited plain of River Kaduna.

4.7 Digital Terrain Model (DTM)

Digital terrain model is a numerical representation of terrain features in terms of elevation and planimetric measurements obtained by sampling a topographic surface. It is a numeric representation of both planimetric detail and height information,which provides a continous description of the terrain surface. The beauty of the DTM is for use with the remotely-sensed data when overlaid to display the final image in three dimension.

The DTM was created by digitizing the topographic map of the study area. The contour interpretation was then carried out. The DTM was now visualized in 3D using a geo-referenced 3D. The general 3D view of the project area landscape can clearly be seen from the DEM in Fig. 4.8.

4.8 Digital Elevation Model (DEM)

In Figure 4.8, it could be seen that the resultant digital elevation model has given a 3D view of the landscape of the project area with the display of drainage channels in blue. The light blue portions show the floodable areas , which were obtained by using the GPS observations from the responses of the questionnaires that was administered. The DEM displayed orthographically illustrates the configuration of the terrain using the 3-D operation of the Arcview software. The upper and lower part of the image shows areas of high relief that conforms with what was obtained from the source topographic map. (see Fig.1.2). The central area shows a low elevation area into which the streams run into the main river as confirmed from source data (see Fig. 1.3).

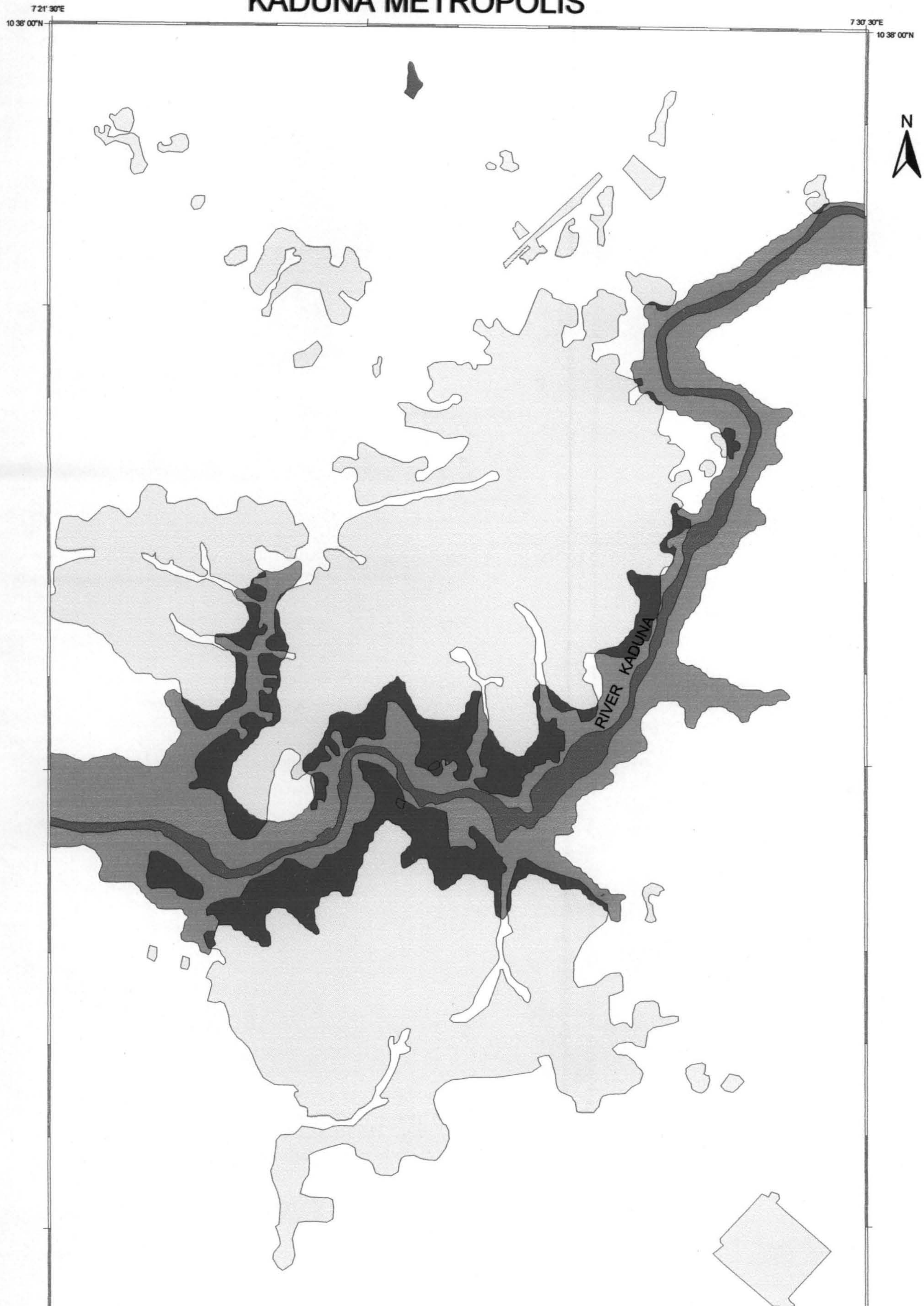
4.9 Spatial Database Query by attributes.

An important aspect of a G.I.S. technology is the ability to carry out spatial query on a database, once created. The query retrives already stored information in the user- defined format.

To demonstrate the effectiveness of the database created , it was subjected to spatial query by attributes. Display of names of settlements within the study area are as shown in Table 4.1.

Table 4.2 displayed the attributes of the settlements within the floodable risk zone within the study area. This query was emphasized upon as it provided answers to the question that would be required by the author in making decisions on flooding within the study area.

KADUNA METROPOLIS



Source: Existing Topo. Map(1972) & GPS Points (2004)

Scale:- 1:110000

LEGEND

- Flood Risk Zone
- River Kaduna
- Floodable area

Fig. 4.7 Vector Layer Showing Floodable areas within Built-up area (Flood Risk Zones)

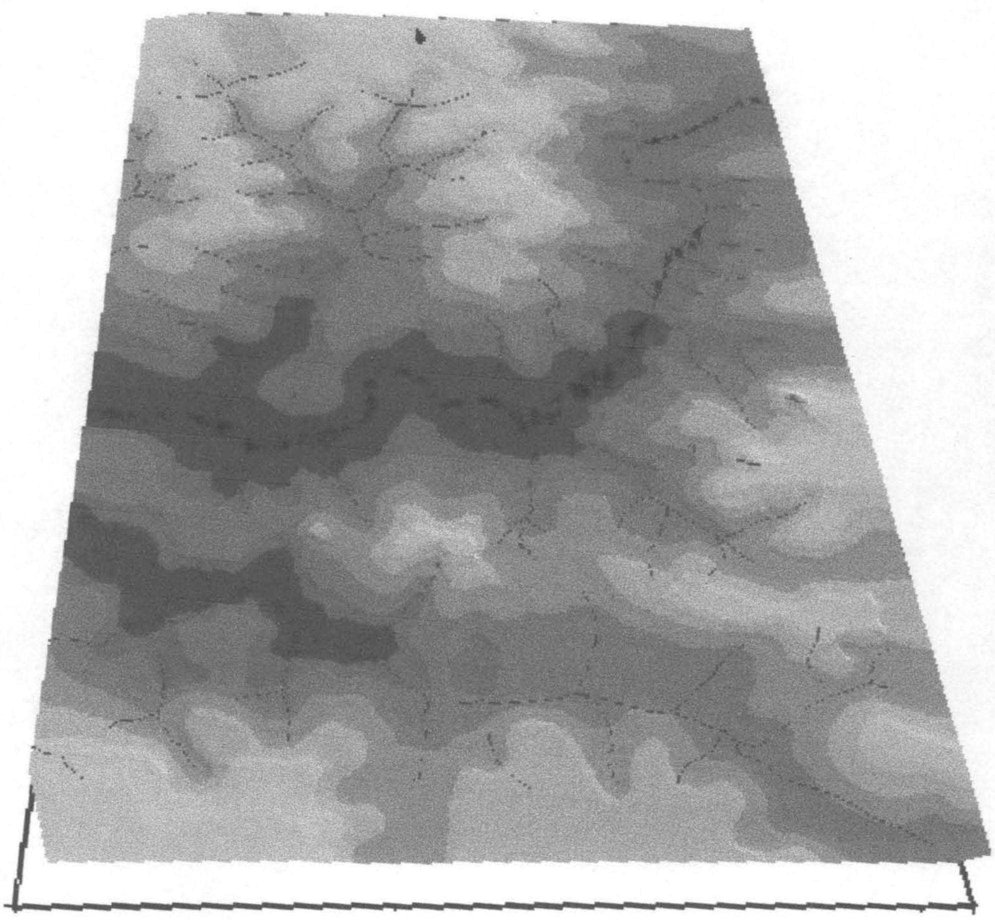


Fig. 4.8: Digital Elevation Model (DEM) of Kaduna Metropolis (Adapted from Topographic Map 1972) and GPS Heights (2005).

Tabel 4.1 Attribute table showing names of settlements within Kaduna Metropolis.

Shape	ID	Area	Name
Polygon	1	161100	N. D. A.
Polygon	2	310620	N. D. A.
Polygon	3	150234	N. D. A.
Polygon	4	59665	School
Polygon	5	129635	Mando
Polygon	6	2212134	Mando
Polygon	7	182441	Mahuta
Polygon	8	44652	N. E. C.
Polygon	9	52740628	Doka
Polygon	10	13591120	Rigasa/Kabala W.
Polygon	11	23965	Airforce Base
Polygon	12	101026	Airforce Base
Polygon	13	348764	N. T. I.
Polygon	14	244935	Ungwan Gwari
Polygon	15	451304	Old Airport
Polygon	16	210009	Old Airport
Polygon	17	57810	Old Airport
Polygon	18	221129	Kaduna Dairy
Polygon	19	239387	Village
Polygon	20	485772	Kawo extension
Polygon	21	210086	Malali
Polygon	22	79343	Malali
Polygon	23	176763	Tudun Wada
Polygon	24	41190224	Kaduna South
Polygon	25	46211	Settlement
Polygon	26	37128	Settlement
Polygon	27	638691	Kudenda
Polygon	28	2983036	N. N. P. C.
Polygon	29	107506	Ungwan Boro
Polygon	30	205459	Ungwan Boro
Polygon	31	145148	U/Na-Mai Gero
Polygon	31	26113	CES Kaduna Poly
Polygon	32	27524	Stadium

Source: Author's work (2005)

Table 4.2 Attribute table Flood Risk Zones (settlements) within Kaduna Metropolis.

Shape	ID	Area	Area	Perimeter	Name
Polygon	9	52740628	52953408.000	96145.430	Doka
Polygon	10	13591120	52953408.000	96145.430	Kabala West
Polygon	19	239387	52953408.000	96145.430	Village
Polygon	20	485772	52953408.000	96145.430	Kawo Extension
Polygon	21	210086	52953408.000	96145.430	Malali
Polygon	23	176763	52953408.000	96145.430	Tudun Wada
Polygon	24	41190224	52953408.000	96145.430	Kaduna South
Polygon	27	638691	52953408.000	96145.430	Kudenda
Polygon	31	26113	52953408.000	96145.430	CES Kaduna Poly
Polygon	32	27524	52953408.000	96145.430	Stadium

Source: Author's work (2005)

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Kaduna metropolis have been experiencing devastating occurrence of seasonal flood resulting in lost of many lives and properties worth millions of Naira. Many factors have been attributed to this perennial environmental problem such as construction of drainage channels to allow free flow of surface water causing flooding.

This project was aimed at attempting to use remotely sensed data and geographical information system in modeling of flood-prone areas along the inhabited plain of River Kaduna within Kaduna metropolis which are under the threat of future flooding. These new technologies have proved advantageous over the conventional field survey in coverage of large areas and provision of viable information in other regions of the electromagnetic spectrum that is invisible with the human eye.

The project area, Kaduna metropolis, is located within latitude 10^{O} 29'N to 10^{O} 37'N and longitude 7^{O} 22'E to 7^{O} 30'E. The land has a gentle slope towards the major drainage which is the River Kaduna traversing the city center towards the south west outskirt of the town picking up tributary drainage water courses.

The remotely-sensed data used in this project was spot XS, 1994. ERDAS (Earth Resources Data Acquisition System) imagine software which is an image processing software was used for the on-screen visual interpretation to obtain the four layers, namely settlements, road networks drainages. ARC/INFO GIS software was used to digitize the topographical map of the study area to obtain the Digital Terrain Model data.

The SPOT image data was enhanced using both the spatial and spectral methods. In addition to the satellite – derived information for proper interpretation of analyzed results, a social field survey in form of questionnaire (see appendix ii) was conducted to ascertain the maximum flood limits. GPS readings were taken to obtain the heights.

GIS overlay by intersection operation was carried out with the four information layers on the buffer created to obtain a model of the flood-prone areas and flood risk zone using Arcview software. The results obtained showed a model of areas along the inhabited plain of River Kaduna within Kaduna metropolis prone to future flood disasters. Furthermore, the model, which portrayed the nature of the problem, would definitely serve as an early warning system (EWS), indicating what can happen at where and when, to the various authorities concerned in order to take timely actions.

In summary, the analyses carried out and the interpretation of results in this report have clearly demonstrated that the floodable areas and the flood risk zones are located across on the central part of kaduna and environs along River Kaduna.

5.2 Conclusion

The result form this study clearly showed that the buffered areas along the inhabited plain of River Kaduna within Kaduna metropolis can be designated as high risk to flooding. The remotely sensed data incorporated into a GIS provided the required model which the conventional field surveying method would not have been able to efficiently produce.

5.3 Recommendations

The primary aim of this project is to model flood-prone areas along the inhabited plain of River Kaduna within Kaduna metropolis. The results obtained showed that areas along the main drainage are recognizable as flood- prone. Based on the results obtained, the following recommendations are considered as being appropriate here:

(1) The authorities concerned should take necessary step to prevent future disaster of the area.

(2) Future studies should make use of higher spatial resolution other than the SPOT XS data use to map flood risk in the area. This would help in identifying and demarcating boundaries of flood-prone areas. These high resolution images,like Ikonos and Quickbird can provide data at 1-meter (or less) resolution to achieve much better results.

(3) NGOs and international organizations/agencies should alleviate the problems of data inadequacies by providing grants and funds to researchers and by establishing remote sensing data banks to make these data readily available, accessible and affordable.

(4) More practical training and skill development programmes should be put in place for researchers, students and remotely-sensed data users at all levels to ensure efficiency and proper handling of available remote sensing and GIS software package and the processing and manipulation of geo-spatial data and data integration so as to encourage expertise in the use of remote sensing data and GIS operations.

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IX I

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA
SCHOOL OF SCIENCE AND SCIENCE EDUCATION
DEPARTMENT OF GOEGRAPHY

QUESTIONNIARE

Flood disasters often lead to lose of lives and property. The victims in most cases lack the data to inform them to either avoid such locations or adopt appropriate reclamation measures. This is an academic research to provide data for the modeling of flooding along the inhabited plain of river Kaduna within Kaduna metropolis.

You are assured that the sincere answers you provide will be used strickly for this research purpose.

1. Date: 2004
2. Location: U/Rimi
3. Name: Aminu
4. Sex: M
5. Age: 38

6. How long have you lived in this area? 4 YEARS
7. Have you ever witnessed any flood disaster here? Yes [✓] No [ ]
8. How many of such floods have you witness? 1
9. In your opinion would you rate the flood as: Extremely devastating [✓], Very devastating [ ], Moderately devastating [ ], Slightly devastated [ ]
10. Has the government on any of the incidence[s] rendered assistance to victims? Yes [ ] No [✓]
11. Do people usually dump refuse into the river? Yes [ ] No [✓]
12. Where is the maximum water level often reached by the flood? [Take GPS readings]. H - 583

X 0332588
Y 1164553

Thanks

APPENDIX II

KADUNA METROPOLIS

Source: Spot XS, 1994