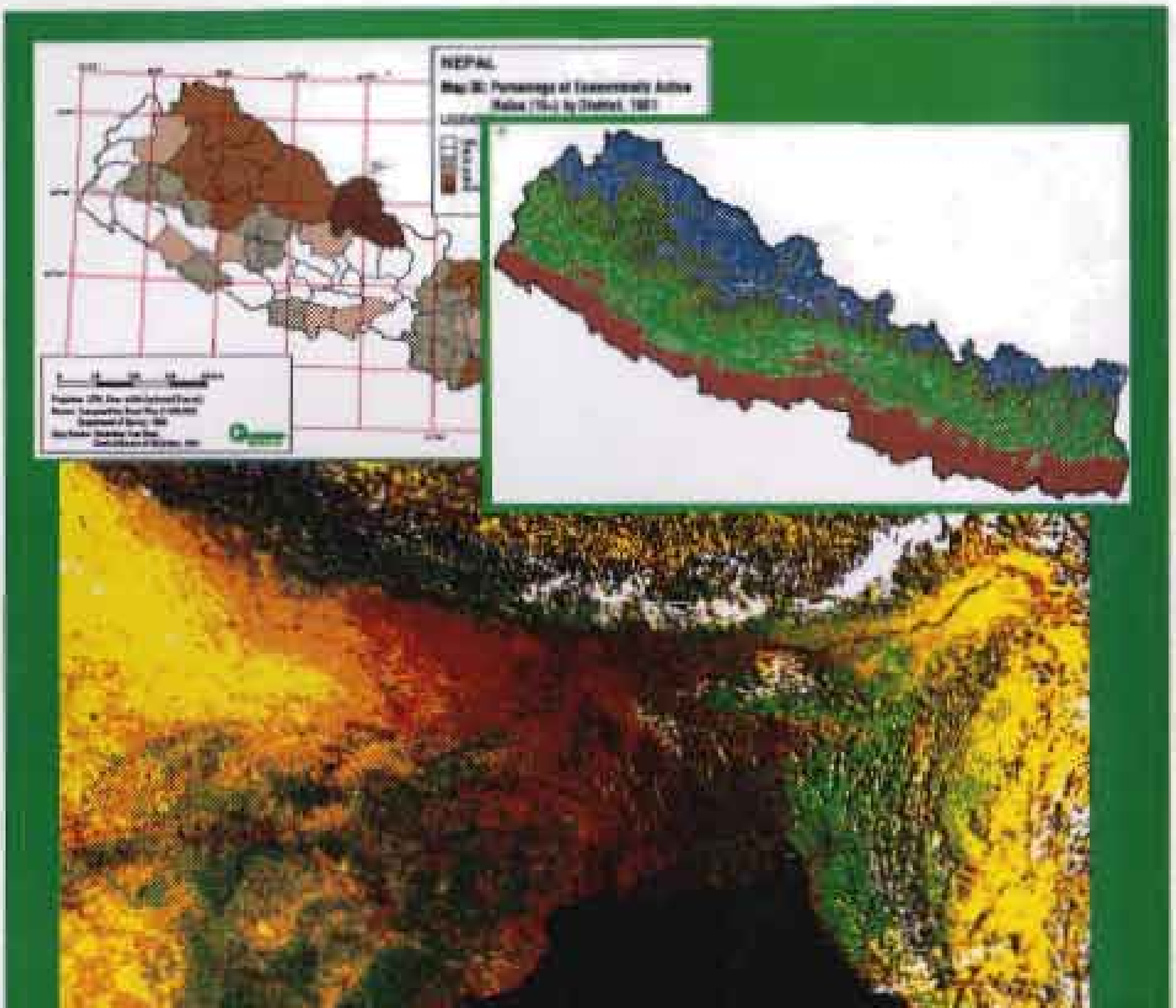
Application of Geographic Information Systems (GIS) and Remote Sensing

Training Manual for Managers (Vol I)



Mountain Environment & Natural Resources' Information Service (MENRIS)
International Centre for Integrated Mountain Development (ICIMOD)

Environment Assessment Programme – Asia and Pacific (UNEP/EAP-AP)

UNEP

Kathmandu, Nepal

ICIMOD

Published by
International Centre for Integrated Mountain Development
GPO Box 3226, Kathmandu
Nepal

Typesetting at ICIMOD Publications' Unit & MENRIS

Application of Geographic Information Systems (GIS) and Remote Sensing

Training Manual for Managers (Vol. I)

Mountain Environment and Natural Resources' Information Service (MENRIS)
International Centre for Integrated Mountain Development (ICIMOD)

Environment Assessment Programme - Asia and Pacific (UNEP/EAP - AP)

Table of Contents

Introduction to the Global Positioning System 209

Geographic Analysis 227

Presenting Results of the Analysis 259

Implementing GIS 269

Foreword

As much as 10 per cent of the world's population and a much larger percentage of the world's poor live in mountain regions. Besides those living in the mountains, an additional 30 per cent of the world's population is affected by or dependent on mountain resources and their management. The Hindu Kush-Himalayan (HKH) region itself sustains approximately 150 million people and affects the lives of more than three times that number in the plains and river basins below.

The HKH Region is not only the world's highest mountain region, but also its largest and most complex. It extends over a distance of 3,500 km, from Afghanistan in the west to Myanmar in the east, and ranges from the Tibetan Plateau of China in the north to the Ganges Basin of India in the south.

Due to the difficult topography of mountain regions, their inaccessibility, and lack of an accurate information base, the decision-making process and implementation of development plans often do not meet the desired expectations. The inherent diversity, marginality, and varying biophysical and socioeconomic values present great impediments to the use of Geographic Information Systems (GIS). The ability to design and implement effective policies and programmes in this dynamic environment is dependent on prompt and thorough analyses of current resource assets, their limitations, and changes. The implementation of GIS can be facilitated if the data are collected, merged, and analysed to provide information and output in a form that decision-makers can understand and use.

Geographic Information Systems (GIS) is one tool that addresses the problems of unscientific and inadequate use and management of the natural resources and environment of the HKH Region. The process of using information in planning and decision-making must be institutionalised, and the information must be in a readily available form. This is where a Geographic Information System (GIS) comes into play. It integrates biophysical and socioeconomic data and indicates alternative strategies for decision-makers.

Despite widespread use of GIS in the global context, in mountain environments it is somewhat limited. The implementation of GIS should be considered in a different perspective for mountain regions than in the lowlands. The lack of experience in handling truly three-dimensional GIS, given the prevailing technology, and dearth of trained manpower and accurate multi-sectoral data hinder appropriate application.

Furthermore, the institutional hurdles are greater than the technological hurdles. A complementary approach between various institutions is indispensable for success in implementing GIS.

The technology is gaining increasing importance, because it is estimated that more than 70% of all decision-making processes are either influenced or dictated by some sort of geographic information. The basic advantage of the technology is its ability to manage and perform complex processing of spatial data and their visualisation impact. Without an integrating methodology, identifying viable technological and institutional options for sustainable development of mountain areas is not possible.

Today, a considerable amount of data on the natural resources of the HKH Region is available through satellite, and this is essential for monitoring the ever-changing resource base. Advances in satellite image-processing and computer analysis have made it possible to evolve a realistic, accurate, and uniform database. Resource assessment and monitoring data are becoming widely available and are being distributed in formats affordable even by local resource-planning and management agencies.

Surendra Shrestha	Egbert Pelinck
Regional Coordinator	Director General
UNEP/EAP-AP	ICIMOD
AIT-Bangkok, Thailand	Kathmandu, Nepal

Purpose of the Workshop

The purpose of the current workshop is four-fold as follows:

i. to make participants aware of GIS and RS technologies for data analysis,
ii. to brief the participants on how GIS could be used effectively for decision-making and modelling purposes,
iii. to advocate the use of GIS technology for planning purposes and implementation strategy, and
iv. to provide hands-on experience and demonstration on applicability of GIS technology.

A three-day awareness-cum-training programme on GIS and RS technologies is being organised for project leaders, project managers, and other senior executives. The programme seeks to provide the latest information on GIS and RS technologies and their application to various disciplines, including hands-on exercises on the use of GIS and RS technology for planning and decision-making. Participants are expected to have some previous exposure to Information Technology and basic computer skills in order to take full advantage of the awareness-cum-training programme.

Expected Impact

The participants will be exposed to GIS and RS technologies through a series of lectures and hands-on exercises. The training programme will highlight the usefulness of the technology as a planning tool as well as its potential applications. The training programme will emphasise the need for coordination and complementary approaches amongst the institutions that are important for database development, database standards, and exchange of information. The training programme will provide senior executives with relevant inputs in GIS activities in their own field. It is expected that the training programme will be able to fulfill ICIMOD/MENRIS's facilitating role for promoting information exchange on modern technologies useful for sustainable development of mountain areas.

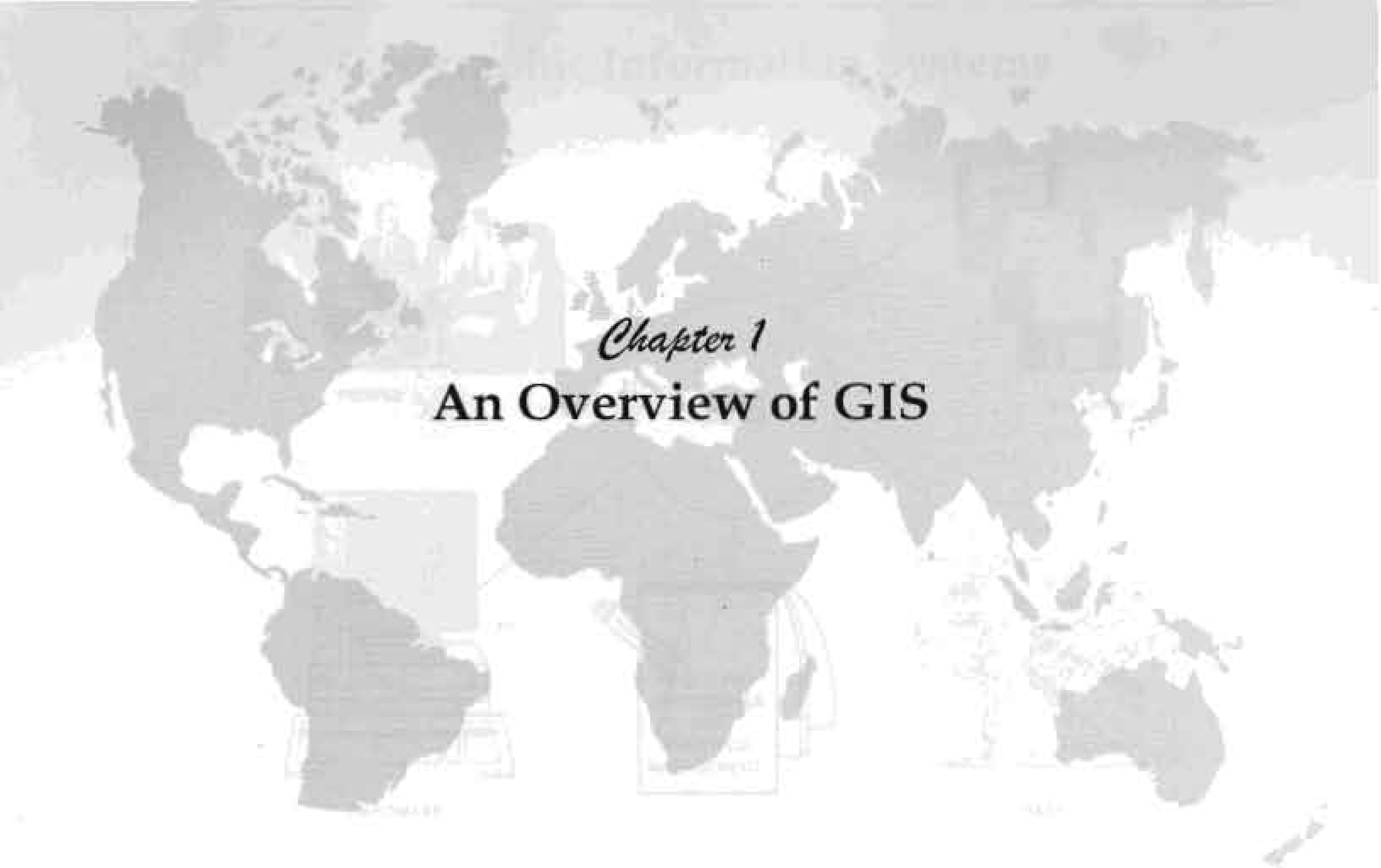
Training Module

Day 1	Introductory Remarks	
	MENRIS Activities	
	Introduction to GIS	Lecture
	Intelligent Infrastructure	A Movie
	Coffee Break	
	GIS Concepts	Lecture
	Introduction to ARC/INFO and Arcview	Lecture/Exercise
	Lunch Break	
	Using a GIS	Exercise
Day 2	Data Capture and Automation	Lecture
	Digitisation	Demonstration
	Coffee Break	
	Spatial Database Concept	Lecture
	Introduction to Remote Sensing	Lecture
	Lunch Break	
	Remote Sensing Application	Demonstration/Exercise
	Introduction to the Global Positioning System (GPS)	Lecture
	GPS Receivers and Data Collection	Demonstration

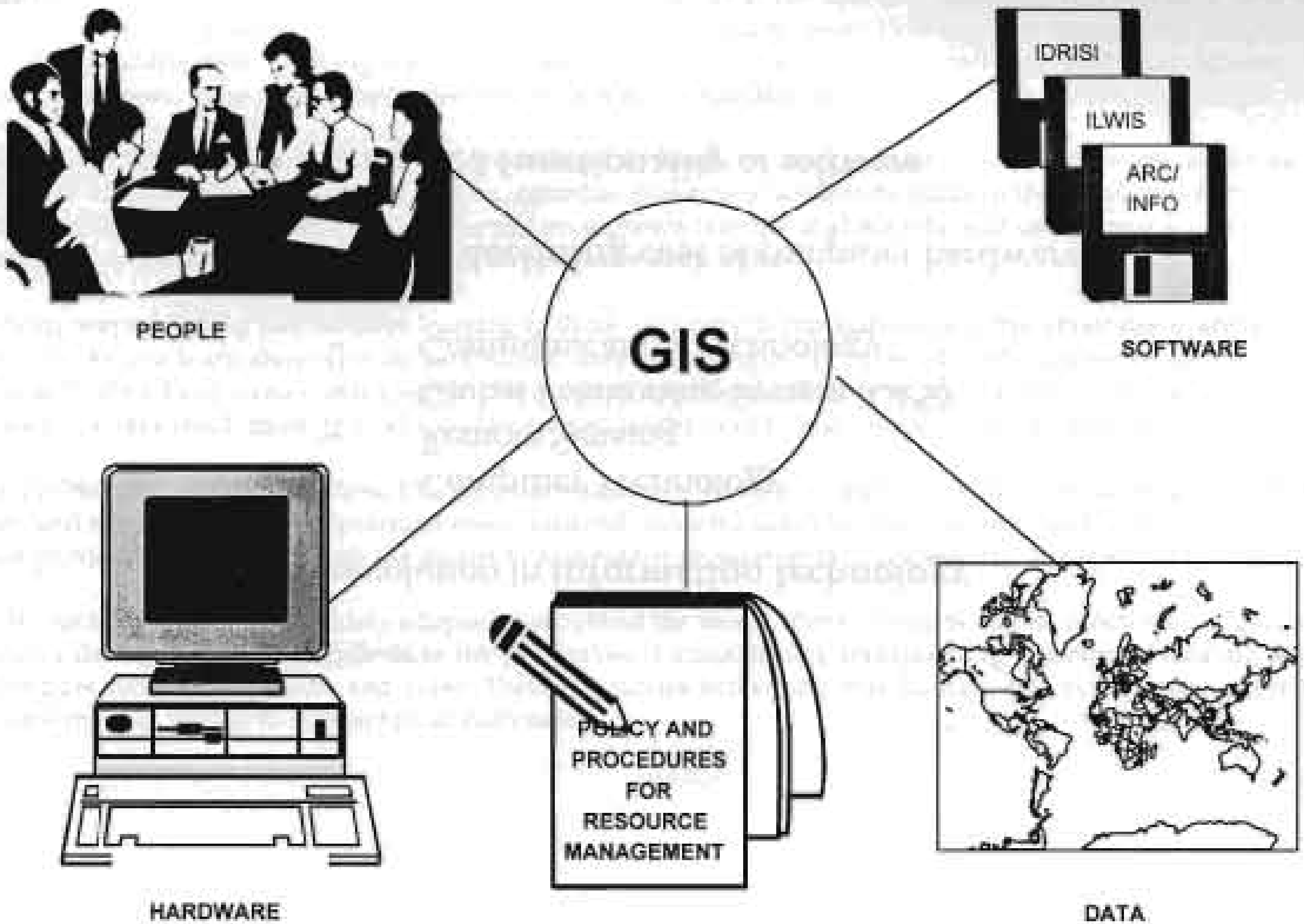
Day 3	Geographic Analysis Database Query	Lecture Exercise
	Coffee Break	
	Buffer Operation	Exercise
	Lunch Break	
	Overlay Exercise	
Day 4	Digital Terrain Model	Exercise
	Coffee Break	
	Network Application	Exercise
	Lunch Break	
	Implementing a GIS Implementation of Specific Issues	Lecture Comments/Experience from Participants
Day 5	Introduction to ARCVIEW	Lecture/Lab Exercise
	Coffee Break	
	Continuation of ARCVIEW Exercise Group Discussions	
	Concluding Session Feedback from Participants Certificate Distribution	

Chapter 1

An Overview of GIS



Geographic Information Systems



- revolution in **information technology**
    - Computer Technology
    - Remote Sensing
    - Global Positioning System (GPS)
    - Communication Technology
- rapidly **declining cost** of computer hardware
- enhanced **functionality** of software

The Philosophy of GIS

GIS has had an enormous impact on virtually every field that manages and analyses spatially distributed data. For those who are unfamiliar with the technology, it is easy to see it as a magic box. The speed, consistency, and precision with which it operates is truly impressive. Moreover, its strongly graphic character is hard to resist. However, the experienced analyst sees the philosophy of GIS quite differently. With experience, GIS becomes simply an extension of one's own analytical thinking. The system has no inherent answers, these depend upon the analyst. It is a tool, just like statistics is a tool. It is a tool for thought.

Investing in GIS requires more than an investment in hardware and software. Indeed, in many instances this is the least of concerns. Most would also recognise that a substantial investment needs to be made in the development of the database. However, one of the least recognised and most important investments is in the analysts who will use the system. The system and the analyst cannot be separated to put it simply, one is an extension of the other.

In many ways, learning GIS involves learning to think – learning to think about patterns, about space, and about processes that act in space. As you learn about specific procedures, they will often be encountered in the context of specific examples. In addition, they will often have names that suggest their typical application. But resist the temptation to categorise these routines. Most procedures have much more general applications and can be used in many novel and innovative ways (Idrisi Student Manual).

The proliferation of GIS is explained by its unique ability to assimilate data from widely divergent sources, to analyse trends over time, and to spatially evaluate potential environmental impacts caused by development. Such advances in information technology have provided governments with the means to address the requirements of spatial data management in developing countries.

As the technology becomes widely adopted throughout the world, there are signs that its functions are gradually changing from those of data collection and analysis to the promotion of visualisation, incorporating a variety of existing data sources and new techniques such as multimedia and video. These techniques will ensure that the data, and in particular geo-reference information, become more accessible to non-technical audiences.

Why GIS?

- 70% of the information includes some geographical facts in the decision-making process
- Ability to assimilate divergent sources of data both spatial and non-spatial (attribute data)
- Visualisation impact
- Sharing of information
- Analytical capability in a spatial context

Why GIS ?

Many professionals, such as foresters, urban planners, and geologists, have recognised the importance of spatial dimensions in organising and analysing information. Whether a discipline is concerned with the very practical aspects of business, or whether a discipline is concerned with purely academic research, geographic information systems can introduce a perspective which can provide valuable insights.

GIS are a means to an end, not an end in themselves. The value of GIS lies not just in the immediate efficiency with which the technology is implemented. Rather, it lies in how the technology helps us to think differently about the way we organise, understand, and use spatial information. New appreciation of the importance of spatial location or geography in real world analysis has emerged from the application of GIS technology. Predictions suggest that billions of dollars will be spent on GIS technology and its applications. The basic factors affecting the diffusion of GIS are due to reasons described below.

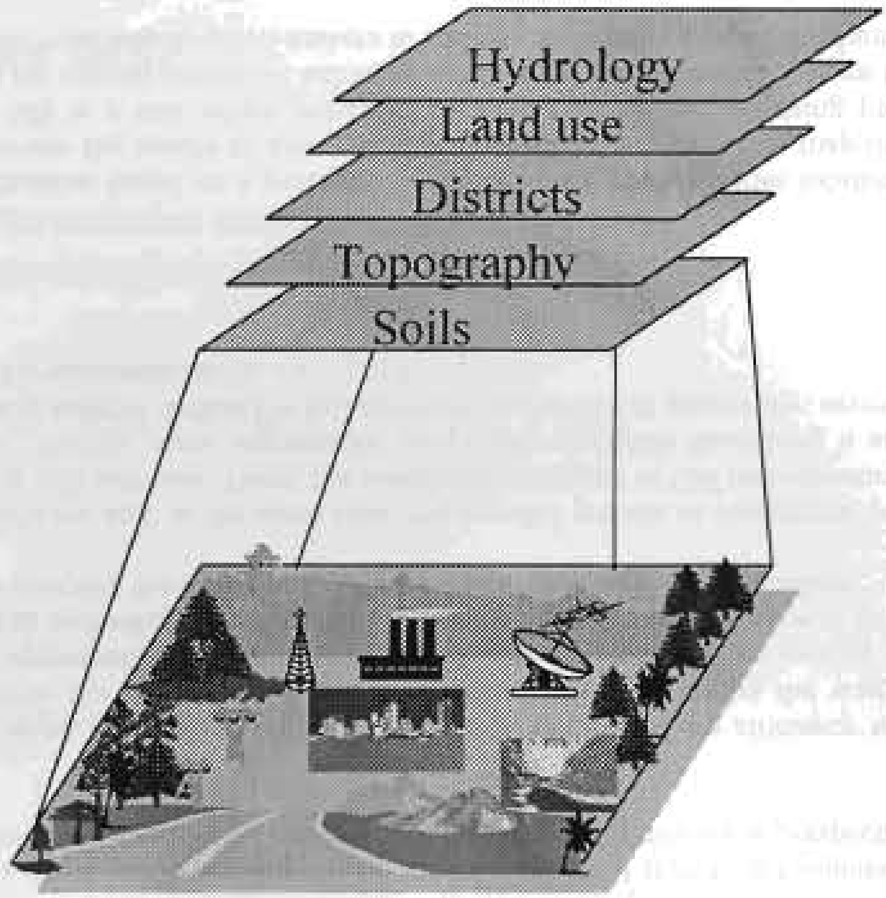
First, the rapidly declining cost of computer hardware and, at the same time, exponential growth of computing power. Second, user-friendly software and increasing functions of GIS software. Third, the visualisation impact of GIS corroborating the Chinese proverb "a picture is worth a thousand words." Fourth, more importantly, geography and data describing it are part of our everyday lives; almost every decision we make is somehow dictated or influenced by some fact of geography; seventy per cent of the decisions, we make are based on geographical considerations.

Thinking Spatially

Thinking spatially is a method of assessing a situation based on a perception of information that includes location. Part of this method would typically include the ability to review the results of assessment or analysis in the form of a map or some sort of report which identifies a geographic location. GIS is a tool which enhances decision-making and planning processes. Most planning applications, be they environmental or for natural resources, urban or agricultural development, require this approach. The three-dimensional spatial analysis ability of GIS can help decision-makers to address the mountain-specific planning processes in a more realistic way.

GIS

A computer-based system, capable of holding and using data describing places on the earth's surface.



The real world consists of many geographies which can be represented as a number of related data layers.

GIS Definition

Geographic data have traditionally been presented in the form of a map. Large-scale development of computer hardware and software is increasing the use of maps dramatically. Many organisations now spend a large amount of money on Geographic Information Systems (GIS) and on geographic databases. The costs of computer hardware and software are decreasing rapidly, and programmes are becoming more user-friendly, making GIS accessible to a large number of people.

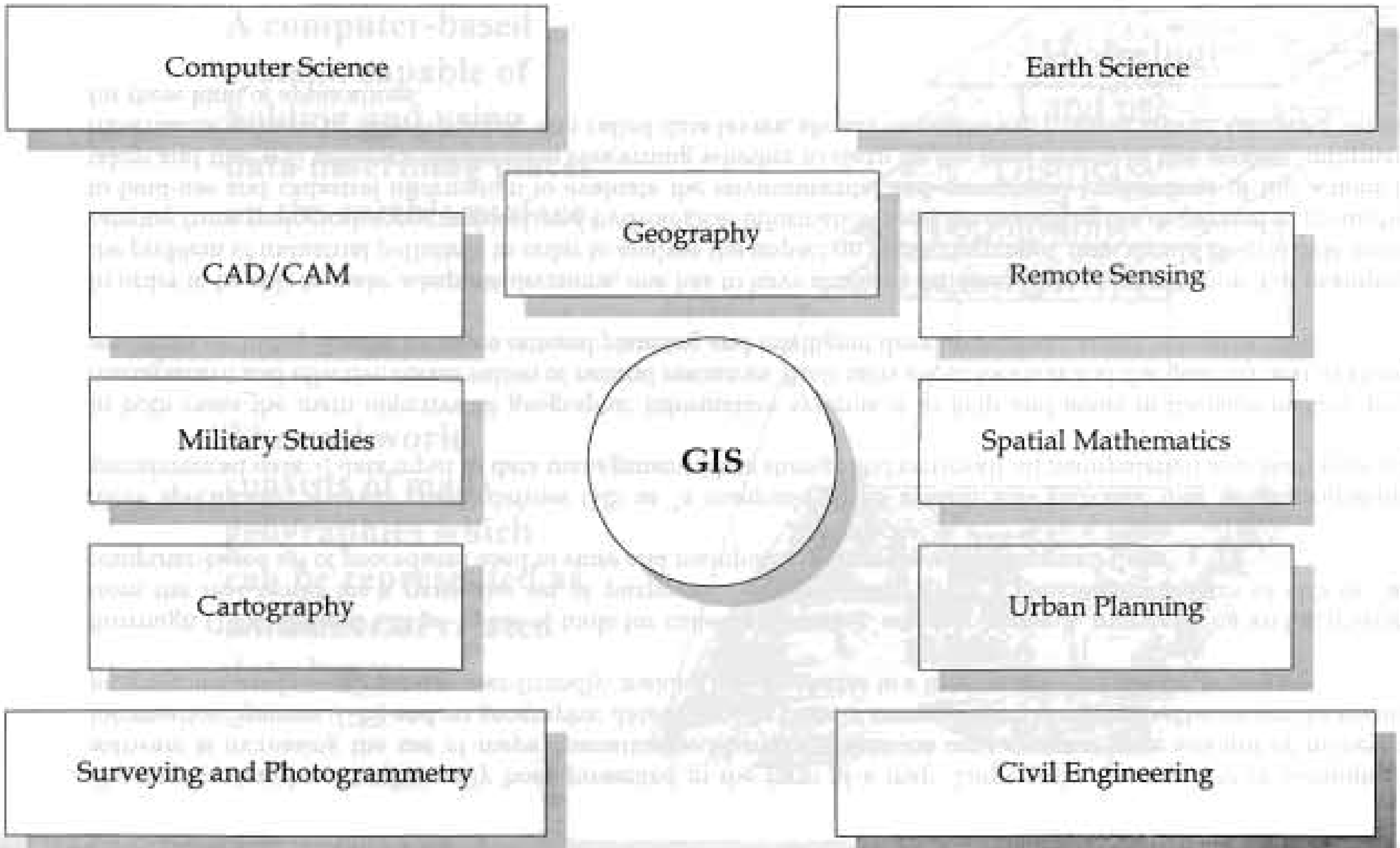
Burrough (1986) defines GIS as "a set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes." Aronoff (1989) gives a general description of GIS as "any manual or computer-based set of procedures used to store and manipulate geographically-referenced data."

More specifically, Aronoff (1989) defines GIS as "a computer-based system that provides four sets of capabilities to handle georeferenced data: i) data input ii) data management (data storage and retrieval) iii) manipulation and analysis iv) data output."

In both cases the main objective of geographic information systems is to help and assist in decision-making processes for the management and effective conservation of natural resources. Basic facts about location and the quantity and availability of natural resources are indispensable for more rational planning and intelligent development of natural resources.

In order to be able to make adequate decisions, one has to have access to different sorts of information. For example, in the case of the problem of industrial pollution, in order to analyse the impact on the environment, data should be available on various aspects, ranging from geological, topographical, and hydrological information used for modelling the dispersion of groundwater pollution to land-use and cadastral information to evaluate the environmental and economical implications of the actions that should be taken and that will influence the decision concerning whether to clean up the mess or not. In this process, information of various dimensions, present in different maps, also called data layers, should be combined. In other words, GIS are a very important tool for these kind of applications.

GIS Historical Development



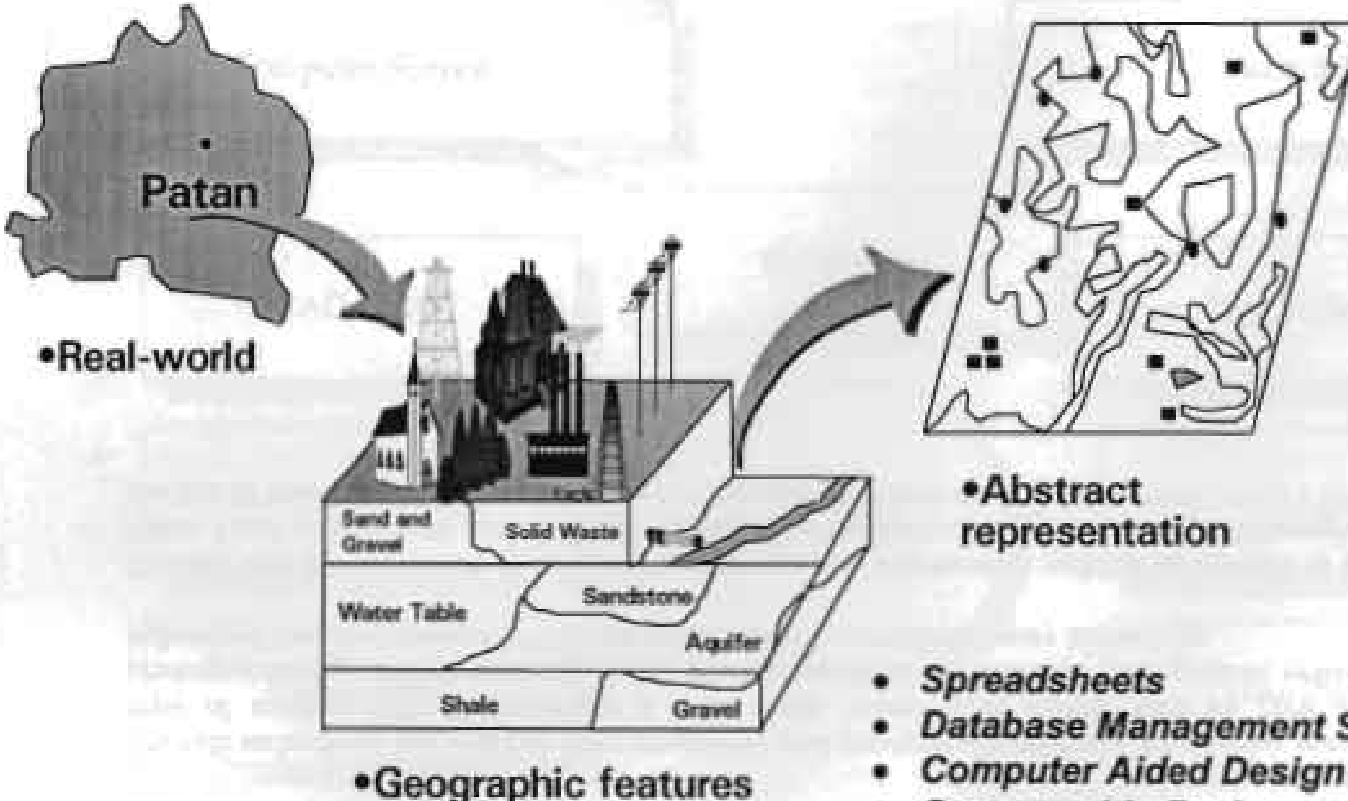
History of GIS

GIS, and the beginnings of simple spatial analysis, would not exist without geography and cartography. The contributions made by information and systems' development, in conjunction with the advancement in computer technology, have made GIS a powerful analytical tool.

The GIS technology has evolved from geography and geo-type disciplines. Cartographic map production can be taken as the first type of manual GIS. However, at a later stage, many other fields, such as civil engineering, computer cartography, photogrammetry, remote sensing, global positioning systems, database management systems, earth sciences, and so on have influenced the development of GIS and made it a truly interdisciplinary technology.

Canada was the pioneer in development of geographic information systems as a result of innovations dating back to the early 1960s. Much of the credit goes to Roger Tomilson for the early development of GIS. Although the field of GIS has been around for the last 25 years, the real potentials have become apparent only since the late 1980s.

Handling Geographic Information



- *Spreadsheets*
- *Database Management Systems (DBMS)*
- *Computer Aided Design (CAD)*
- *Cartographic Packages*
- *Photogrammetrical Software*
- *Image Processing Software*

Spatial Operations

Many computer programmes can handle geographic data such as those described below.

Spreadsheets (e.g., Lotus 1-2-3, QuatroPro). A spreadsheet can be thought of as a large imaginary piece of electronic paper that can contain information in rows and columns, which is used for all sorts of (mathematical) operations for producing graphs. Spreadsheets are often used in combination with GIS.

Database Management Systems (e.g., Oracle, dBase). A Database Management System (DBMS) is a set of programmes which is a collection of information about things and their relationships to each other and which maintain and manipulate data in a database. A DBMS only handles "attribute data" and cannot handle maps. It generally forms an integrated part of GIS.

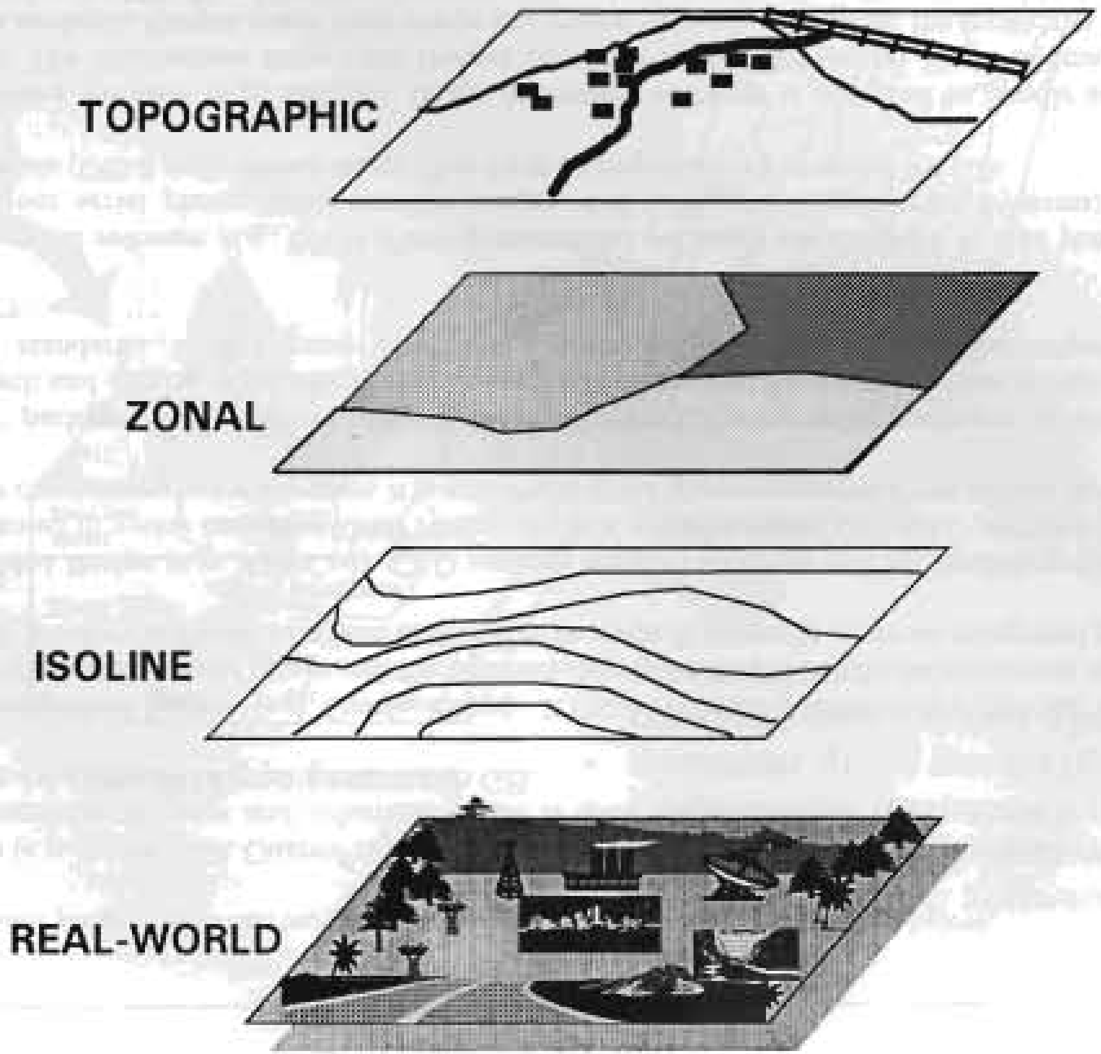
Computer Aided Design (e.g., AutoCad). CAD systems are for capturing and manipulating drawings. Point, line, and polygon objects are stored in vector format. A CAD system is like a part of a vector GIS. CAD software is highly developed and has very good display capabilities, but, on its own, it is neither designed to carry out spatial operations nor use raster data types.

Cartographic packages (e.g., Aldus Freehand, CarthoGraphix). Cartographic packages or desktop mapping systems are for selective search and display of information from spatial databases and for the production of high quality output maps which meet cartographic standards. In this sense, they form a useful addition to GIS, since the output facilities of most GIS are still unsatisfactory.

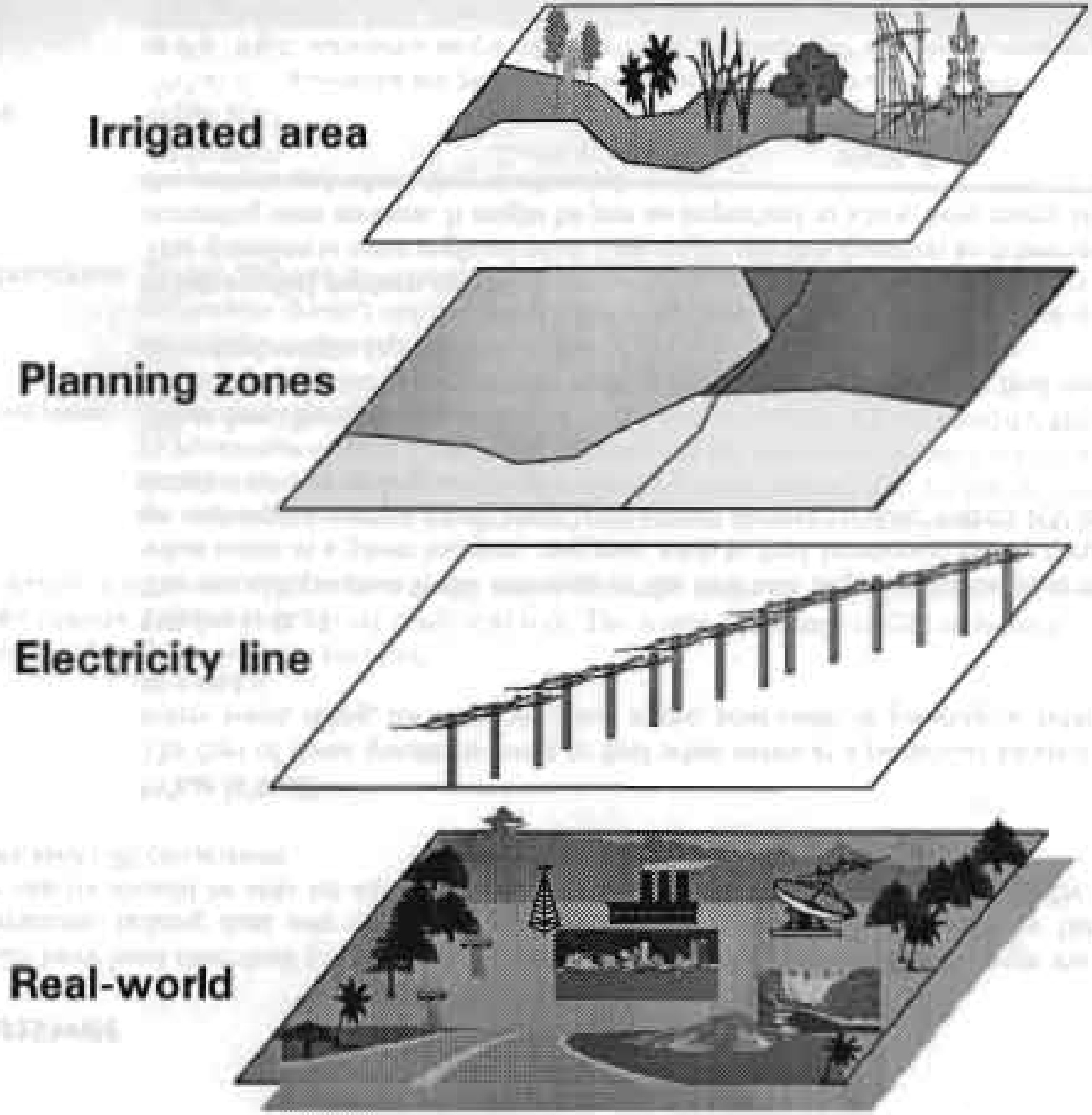
Photogrammetrical software (e.g., DMS). Photogrammetrical packages are designed to take point sample data (mostly of terrain elevations) from aerial photographs, satellite images, and GPS (global positioning systems) data, and then produce digital elevation models (DEM) and contour maps. They form an important input source for GIS.

Image Processing Software (e.g., ERDAS). Image processing software is designed to handle satellite images, or scanned aerial photographs. The information from such images can be extracted by several kinds of image enhancement techniques and classification methods. Output maps from image processing software often form the input into GIS. These software packages are not considered to be GIS. The difference between GIS and other software using geographic data is that only GIS permit spatial operations on the data.

Maps and Spatial Data



What can GIS do?



Questions GIS can answer

Thus far, GIS have been described in two ways: i) through formal definitions, and ii) through the technology's ability to carry out spatial operations, linking data sets together. One can also, however, distinguish GIS by listing the types of questions the technology can (or should be able to) answer. If one considers a particular application carefully, there are five types of question that sophisticated GIS can answer.

Location — **What is at...?**
The first of these questions seeks to find what exists at a particular location. A location can be described in many ways, using, for example, place name, post code, or geographic reference such as longitude/latitude or x and y.

Condition — **Where is it...?**
The second question is the converse of the first and requires spatial data to answer. Instead of identifying what exists at a given location, one may wish to find location(s) where certain conditions are satisfied (e.g., an unforested section of at least 2,000 square metres in size, within 100 metres of a road, and with soils suitable for supporting buildings).

Trends — **What has changed since...?**
The third question might involve both of the first two and seeks to find the differences (e.g., in land use or elevation) within an area over time.

Patterns — **What spatial pattern exists...?**
This question is more sophisticated. One might ask this question to determine whether landslides are mostly occurring near streams. It might be just as important to know how many anomalies there are that do not fit the pattern and where they are located.

Modelling — **What if...?**
"What if.." questions are posed to determine what happens, for example, if a new road is added to a network or if a toxic substance seeps into the local groundwater supply. Answering this type of question requires both geographic and other information (as well as specific models). GIS permits spatial operation. For example:

Name	Latitude	Longitude	Population
Kathmandu	27°42′ N	85°20′ E	421258
Lalitpur	27°41′ N	85°18′ E	115865
Bhaktapur	27°40′ N	85°26′ E	61405

Aspatial questions: Asking "What's the average number of people working with GIS in each location?" is an aspatial question - the answer doesn't require the stored value of latitude and longitude; nor does it describe where the places are in relation to each other.

Spatial questions: "How many people work with GIS in the major centres of Kathmandu Valley", or "Which centres lie within 10 kilometres of each other?", or "What's the shortest route passing through all of these centres?" These are spatial questions that can only be answered using latitude and longitude data and other information such as the radius of the earth. Geographic Information Systems can answer such questions.

GIS are not simply a computer system for making maps, although maps on different scales are created in different projections and with different colours. GIS provide a truly analytical tool. The major advantage of GIS technology is that it facilitates identification of spatial relationships between map features.

GIS Questions - Locations - What is at ... ?

Mangal Bazar, Lalitpur District

Identifier Shrestha Niwas

Area	215.712
Owner	Asha Ram Shrestha
Address	14/210 Mahapal
Zoned land use	Residential
Assessment	Nrs. 5,000,000

Who owns the land at Mangal Bazar, and its assessment?

GIS Questions - Conditions - Where is it ... ?

Mangal Bazar, Lalitpur District

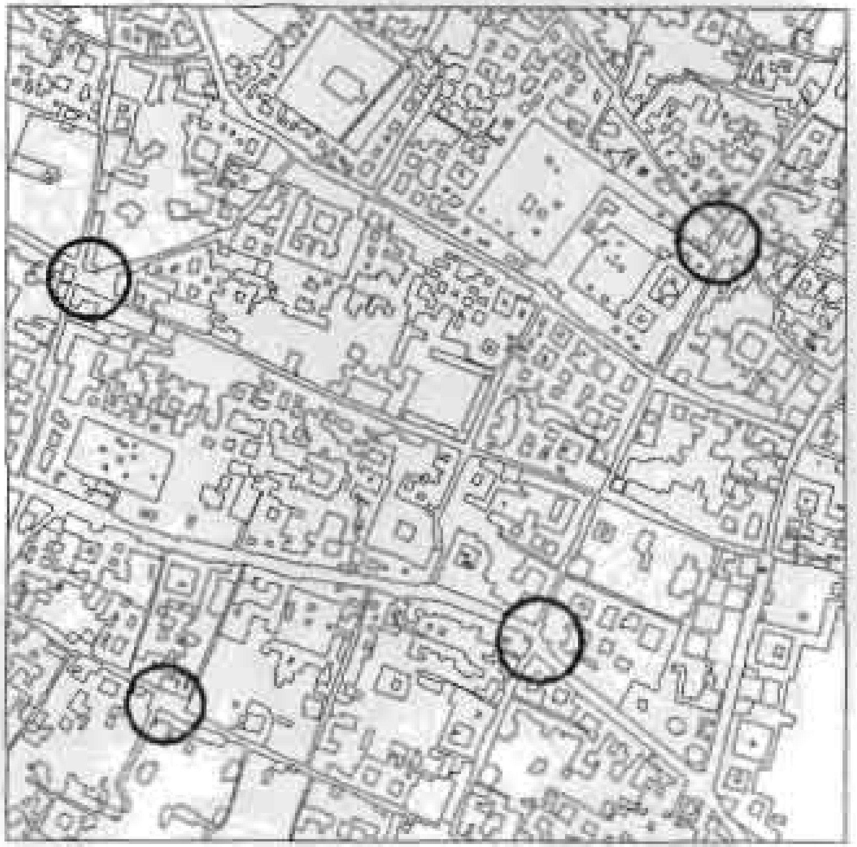
Residential land use

Assessed at less than Rs. 500,000
4 bedrooms
Made of local bricks

Where are houses that you might consider buying located?

GIS Questions - Patterns - What data are related ... ?

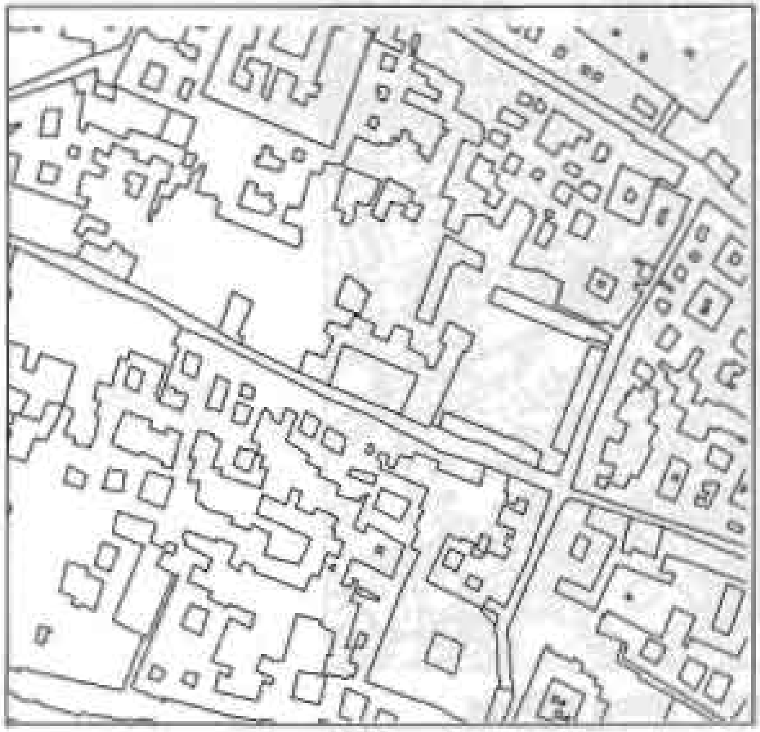
Mangal Bazar, Lalitpur District



What kind of patterns exist that provide potentials for vehicular accidents?

GIS Questions - Trends - What has changed since ... ?

Mangal Bazar, Lalitpur District



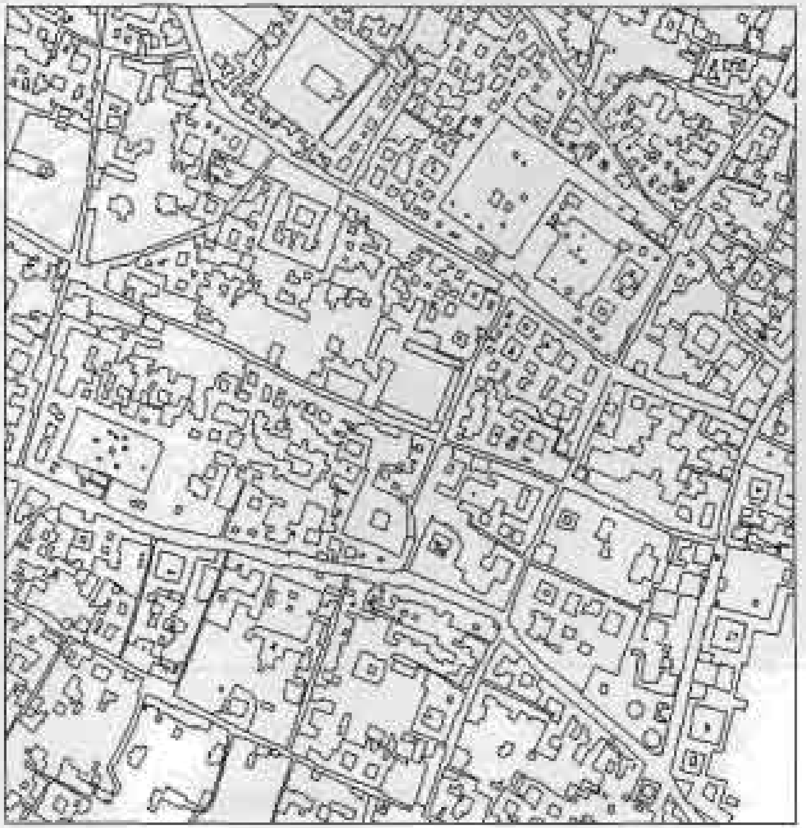
1970

1990

How much land has been used for residential construction since 1970?

GIS Questions - Models - What if ... ?

Mangal Bazar, Lalitpur District

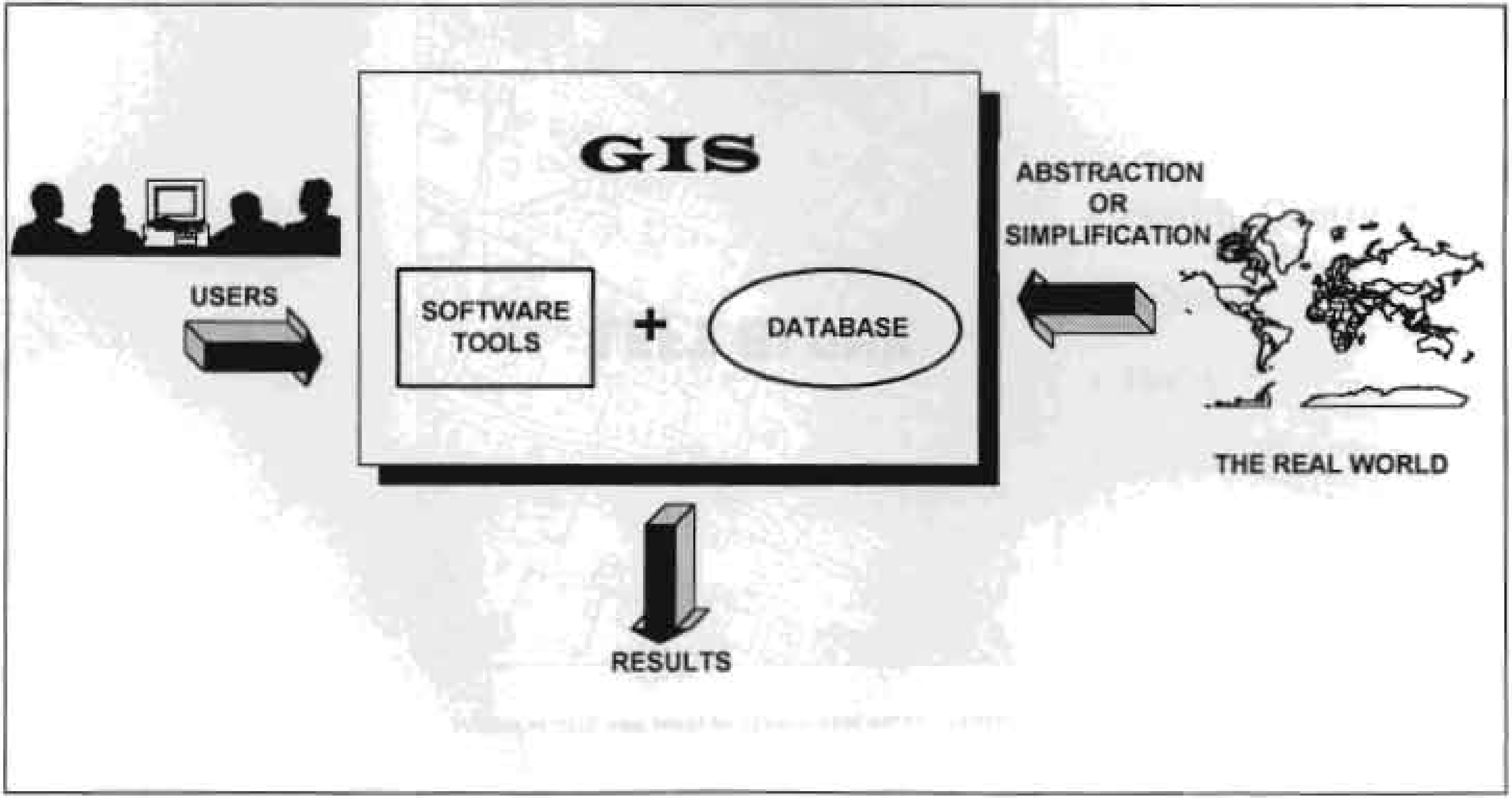


- Health Centre ?
- School ?
- Hotel ?
- Post Office ?

Where would you want to open a new service centre?

LEFT BLANK

Components of GIS



Components of GIS

Several components are involved in GIS technology.

Hardware

A computer and the associated peripherals are essential for handling spatial data in GIS. These devices are collectively known as hardware.

Software

Software refers to the programmes that run on computers; these include programmes to manage the computer and to perform specific functions. For example, Lotus, dBase, WordPerfect, and ARC/INFO are specialised software programmes designed to perform certain tasks.

Database

A central theme to GIS is the database. A GIS database deals with spatial data. GIS facilitate integration of spatial and attribute data and this makes GIS unique in contrast to other database systems. The beauty of GIS technology lies in the ability to assimilate disparate sources of data and analyse them.

Human Input

People who work with GIS form the most important component. GIS constitute truly a interdisciplinary field and require varied backgrounds of expertise, depending upon the applications. In addition, for technical management, a Hardware Specialist, System Administrator, and Database Manager are required for a corporate GIS set-up.

Policy and Procedures

A methodology is a must to derive the results users need. Basically, this includes spatial analysis for the particular appli-cation. By and large, this depends upon the institutional framework and its interest in exploiting GIS technology for decision-making.

Applications of GIS

- Natural Resources' Applications
- Environmental Applications
- Socioeconomic Applications
- Management Applications

GIS Applications

Computerised mapping and spatial analysis have been developed simultaneously in several related fields. The present status would not have been achieved without close interaction between various fields such as utility networks, cadastral mapping, topographic mapping, thematic cartography, surveying and photogrammetry remote sensing, image processing, computer science, rural and urban planning, earth science, and geography.

The GIS technology is rapidly becoming a standard tool for management of natural resources. The effective use of large spatial data volumes is dependent upon the existence of an efficient geographic handling and processing system to transform this data into usable information.

The GIS technology is used to assist decision-makers by indicating various alternatives in development and conservation planning and by modelling the potential outcomes of a series of scenarios. It should be noted that any task begins and ends with the real world. Data are collected about the real world. Of necessity, the product is an abstraction; it is not possible (and not desired) to handle every last detail. After the data are analysed, information is compiled for decision-makers. Based on this information, actions are taken and plans implemented in the real world.

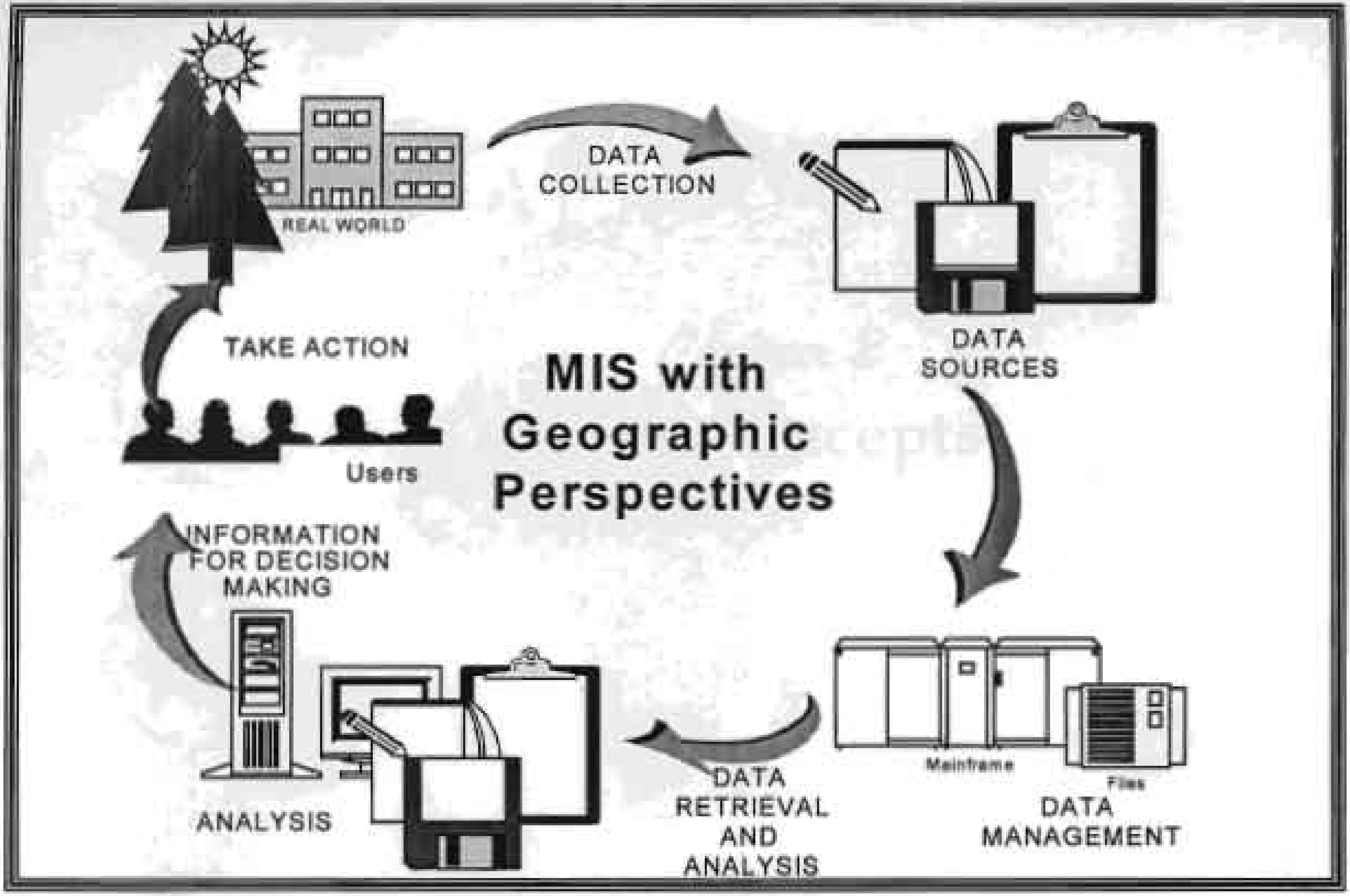
Some typical examples of GIS applications within natural resource planning are:

- land-use planning and management
- mineral exploration
- environmental impact studies
- management of natural resources
- management of water resources
- natural hazard mapping
- forestry and wildlife management
- soil degradation studies
- monitoring desertification
- agricultural development

Sample GIS Applications

- Land-use planning and management
- Mineral exploration
- Environmental impact studies
- Management of natural resources
- Natural Hazard Mapping
- Forestry and wildlife management
- Soil degradation studies
- Monitoring desertification

The Planning Process



Chapter 2

GIS Concepts

Mapping Concepts

Maps have been used since the earliest times to portray information about the earth's surface. A map is also an information system, normally representing on a certain scale and on a flat medium a selection of material or abstract features on, or in relation to, the surface of the earth.

Maps have been used over the centuries to portray geographic information. In the twentieth century, the pace of science and techrology accelerated. This increase in pace created a demand for ever greater volumes of geographic data to be presented in a map form more quickly and more accurately. With the development of reconnaissance technologies, such as aerial photography or satellite-based remote sensing, there has been an explosion of geographic data production, wider use, and more sophisticated analyses. Geographic data are now being generated faster than they can be analysed.

Mapping Concepts

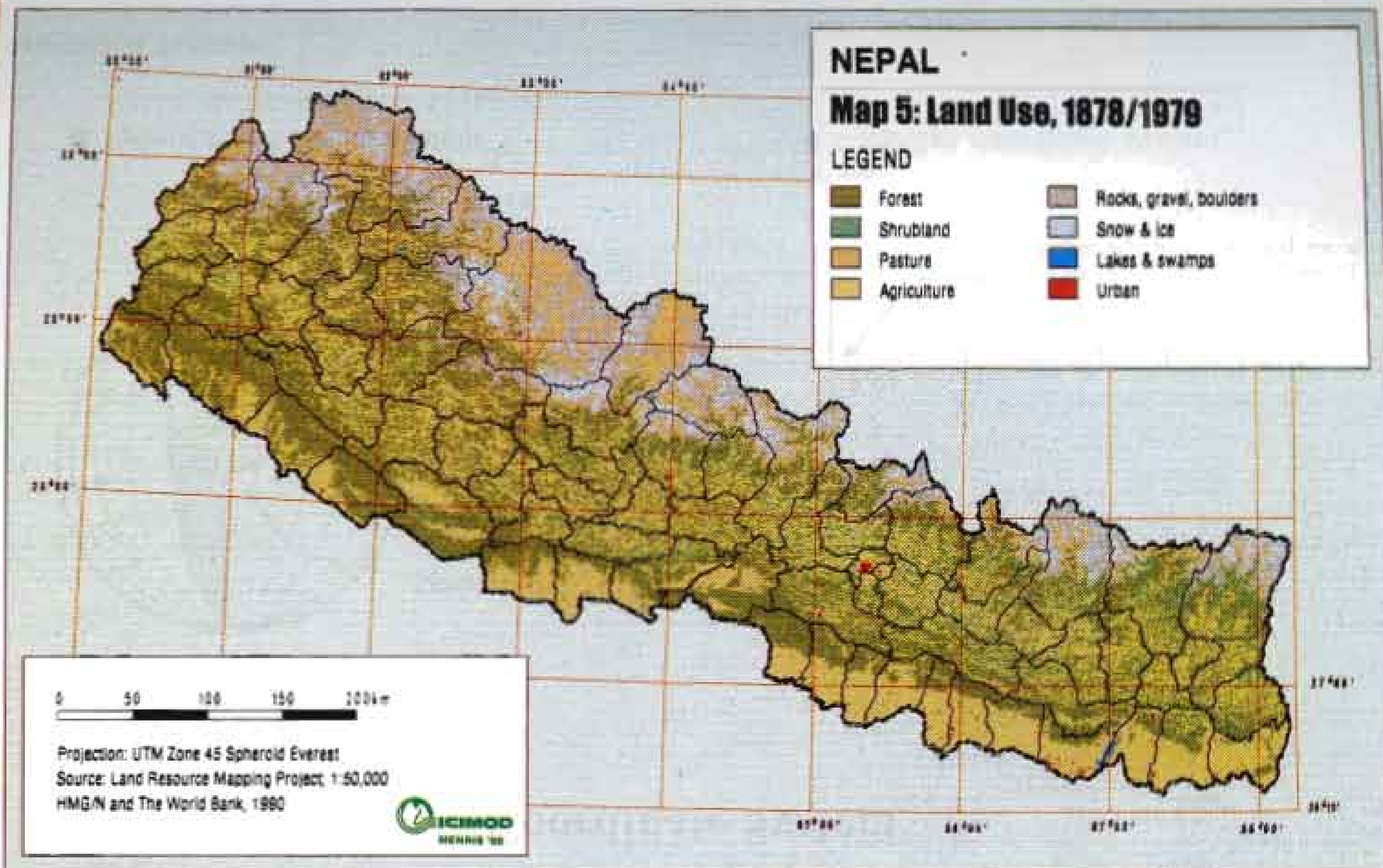
- Provide descriptions of geographic phenomena
- Spatial and non-spatial information
- Map features

Map Features

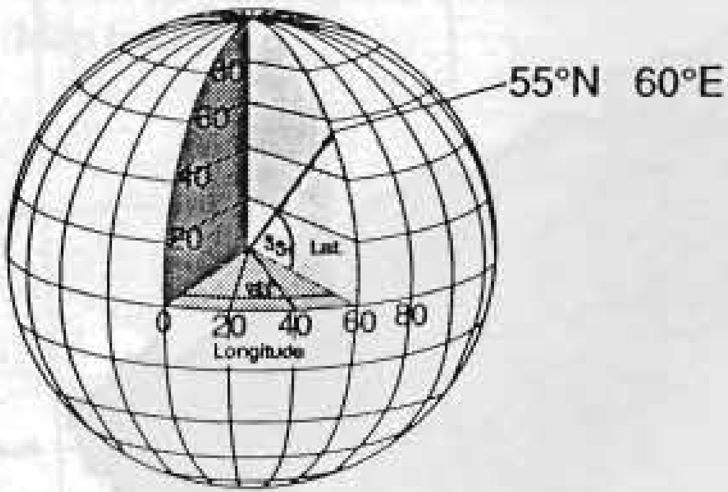
- Point
- Line
- Polygon

Map Properties

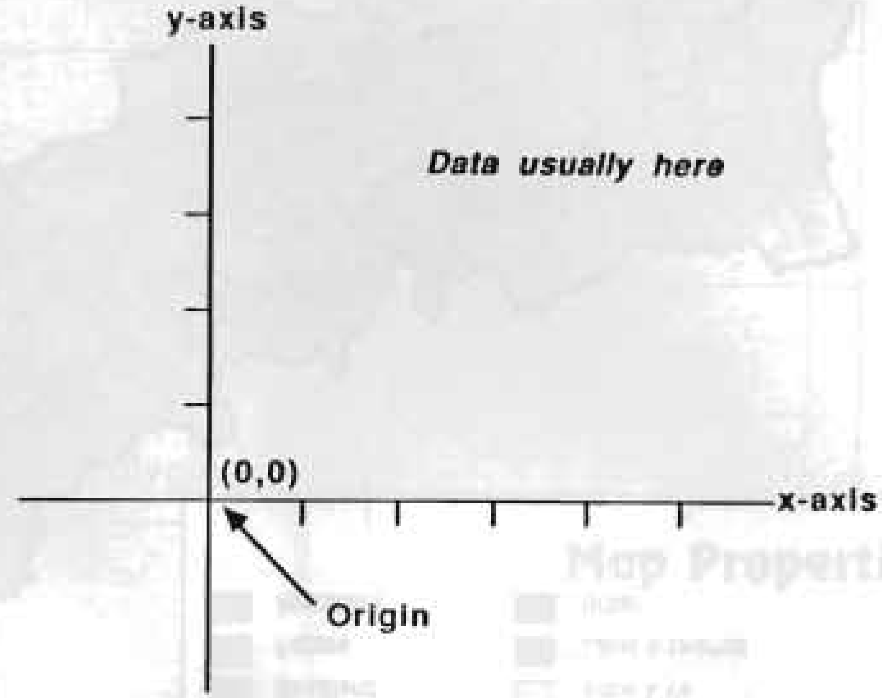
- Scale
- Resolution
- Accuracy
- Precision


NEPAL
Map 5: Land Use, 1878/1979
LEGEND
Forest
Shrubland
Pasture
Agriculture
Rocks, gravel, boulders
Snow & ice
Lakes & swamps
Urban
0 50 100 150 200km
Projection: UTM Zone 45 Spheroid Everest
Source: Land Resource Mapping Project, 1:50,000
HMG/N and The World Bank, 1980
ICIMOD

Coordinate System



■ Spherical coordinate system



■ Cartesian coordinate system

Projection System

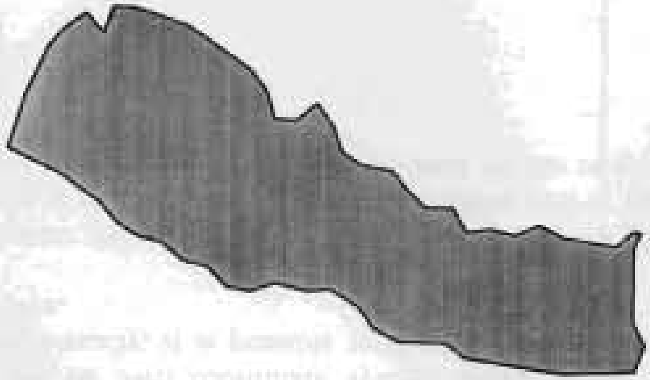
Three important globally used coordinate systems are:

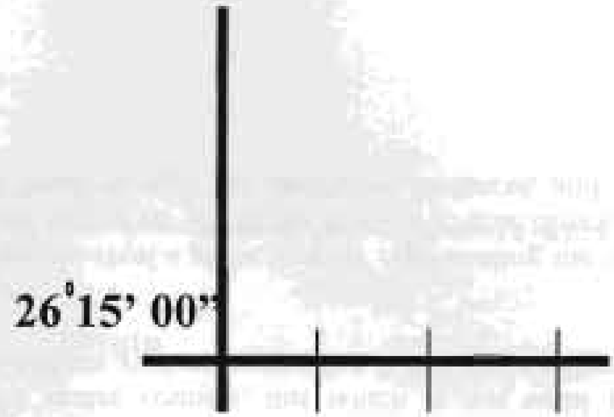
- geographic coordinates (latitude, longitude), (degree, minute, second: DMS),
- UTM (Universal Transverse Mercator) co-ordinates (X,Y) (metres), and
- Lambert Conformal Conic (metres)

Very often a country has its own coordinate system which serves the entire country, but which is not valid for other (neighbouring) countries. Usually, it is possible to change from one coordinate system to another if the specifications of the different systems are known.

Every flat map misrepresents the surface of the earth in some way. No map can rival a globe in truly representing the surface of the entire earth. However, a map or parts of a map can show one or more, but never all, of the following: true directions, true distances, true areas, and true shapes. If the area covered by the map is small enough the directions, distances, and areas are reasonably accurate.

Locating Nepal in Real-World Coordinates





- Global locations
- State Plane Coordinate System
- Latitude & Longitude

The Geographic Coordinate system is a spherical coordinate system composed of parallels of latitude and meridians of longitude. Both divide the circumference of the earth into 360 degrees which are further subdivided into minutes and seconds. Unlike the equator in the latitude system, there is no natural zero meridian. In 1884, it was finally agreed that the meridian of the Royal Observatory in Greenwich, U.K., would be the Prime Meridian.

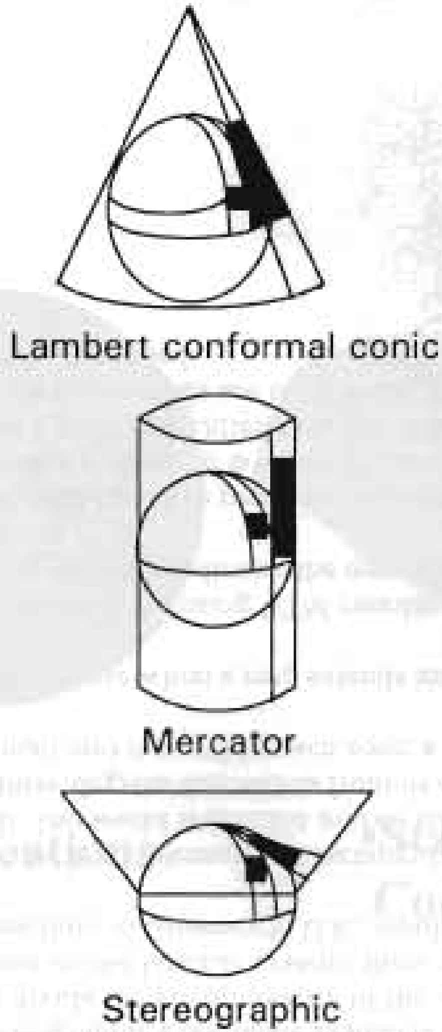
Mercator is an international rectangular coordinate system which extends around the world from 84 degrees North to 80 degrees South. The world is divided into 60 zones, each covering six (6) degrees longitude. Each zone extends three (3) degrees eastwards and three degrees westwards from its central meridian. Zones are numbered west to east from the 180 degree meridian. Because of the small area covered by each zone, a high degree of accuracy is possible. For example, Nepal falls under zones 44 and 45.

Problems arise when a map extends into two UTM zones. The entire map will then have to be projected into one of the two zones.

The advantage of using UTM coordinates is its metric nature. Normal calculations can be performed on UTM coordinates, while for geographic coordinates the minutes and seconds have to be first transformed into the decimal system.

Calculation of a map projection requires definition of the spheroid. As the earth is not a perfect globe (i.e., the earth is 'flattened' at the poles), a spheroid is defined in terms of axes lengths and eccentricity of the earth. Several principal spheroids are in use by one or more countries. Differences are due primarily to calculation of the spheroid for a particular region of the earth's surface. Some important spheroids are the Clarke 1866, the Bessel and the New International 1967. In the HKH Region, in general the Everest spheroid is applied.

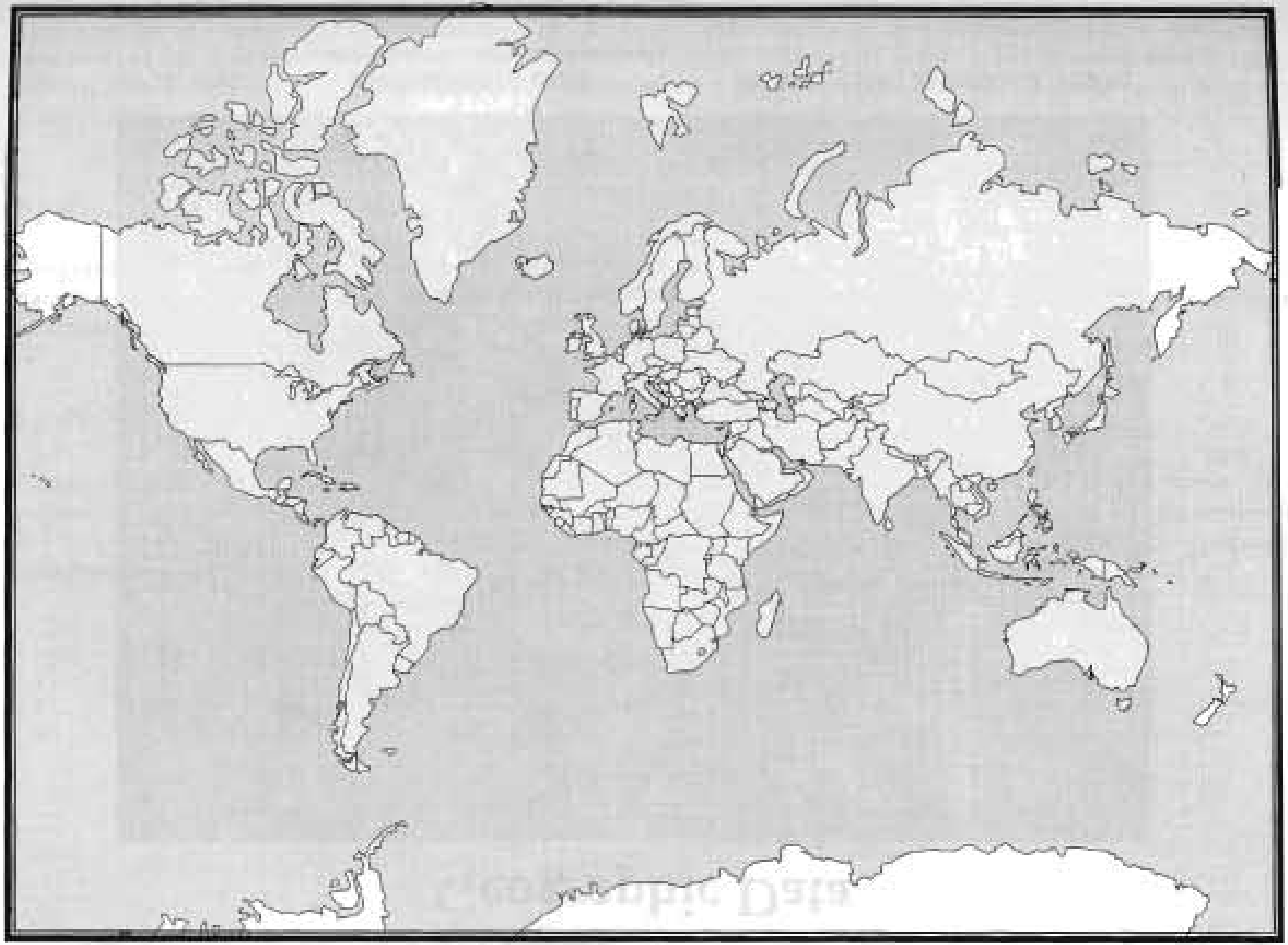
Map Projections



Spatial properties

- ***Shape***
- ***Area***
- ***Distance***
- ***Direction***

Spatial Data for GIS



Geographic Data

SPOT PAN PANCHROMATIC MODE 20 DEC 1988 KATHMANDU NEPAL
(10 m RESOLUTION) 0.5 to 0.7 micrometers

- City Name
- Address range to the airport
- Address range to the park
- Street No., Direction of Travel

Although the two terms, data and information, are often used indiscriminately, they both have a specific meaning. Data can be described as different observations which are collected and stored. Information is data which is useful in answering queries or solving a problem. Digitising a large number of maps provides a large amount of data after hours of painstaking work, but the data can only render useful information if used in analysis.

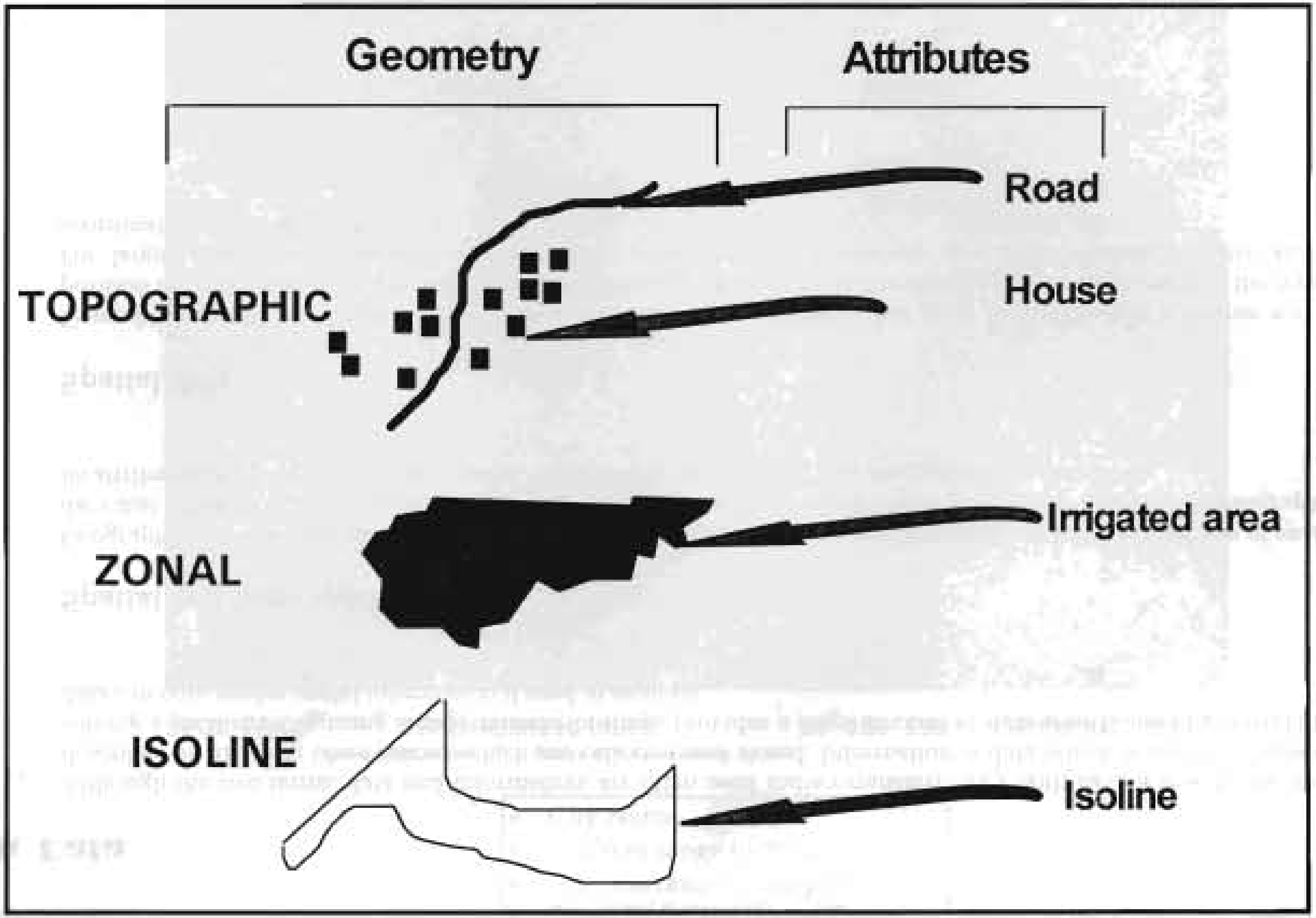
Spatial and Non-Spatial data

Geographic data are organised in a geographic database. This database can be considered to be a collection of spatially referenced data that acts as a model of reality. There are two important components of this geographic database: its **geographic position** and its **attributes or properties**. In other words, spatial data (where is it?) and attribute data (what is it?)

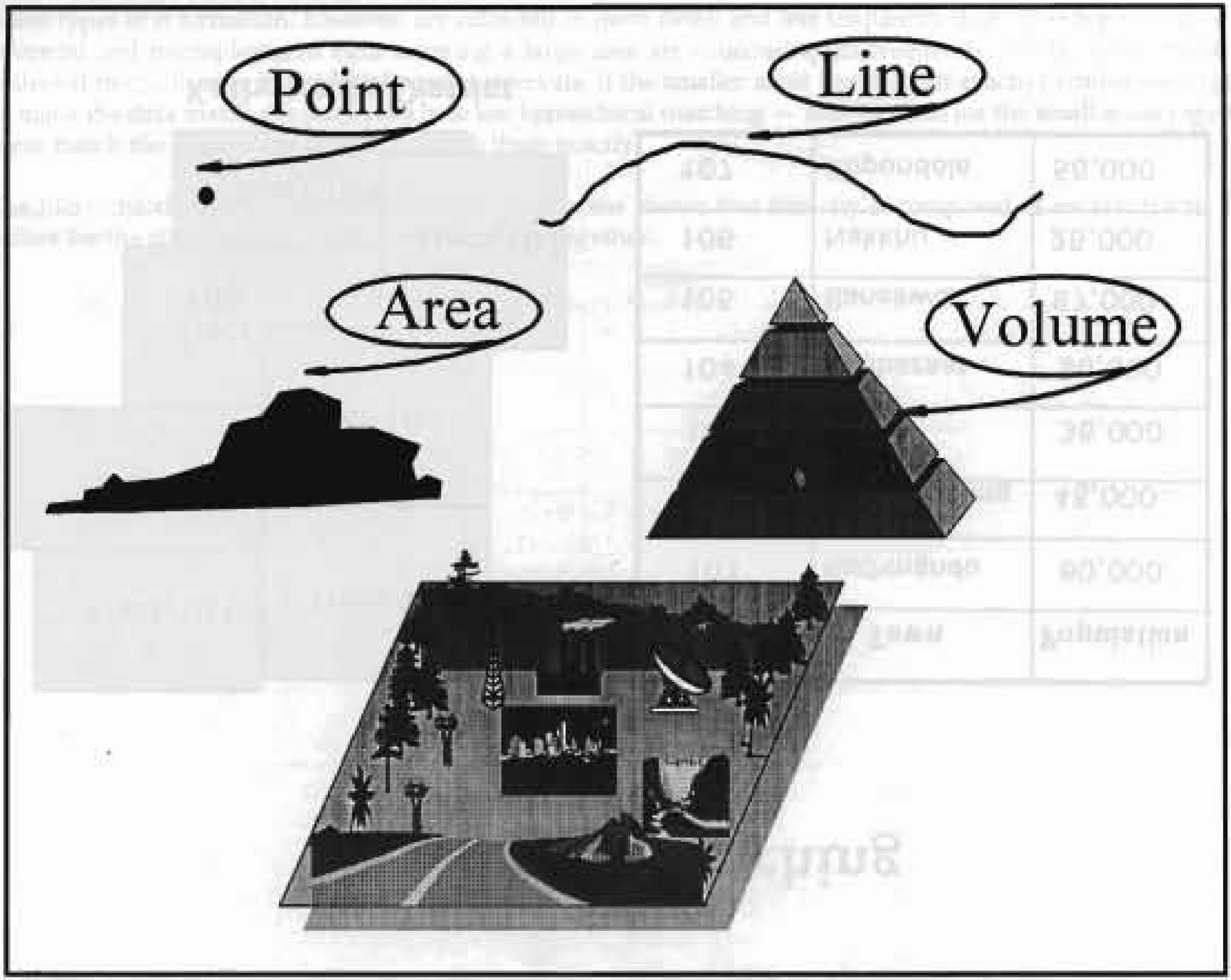
Spatial data

Geographic position refers to the fact that each feature has a location that must be specified in a unique way. To specify the position in an **absolute** way a **coordinate** system is used. For small areas, the simplest coordinate system is the regular square grid. For larger areas, certain approved cartographic projections are commonly used. Internationallly there are many different coordinate systems in use.

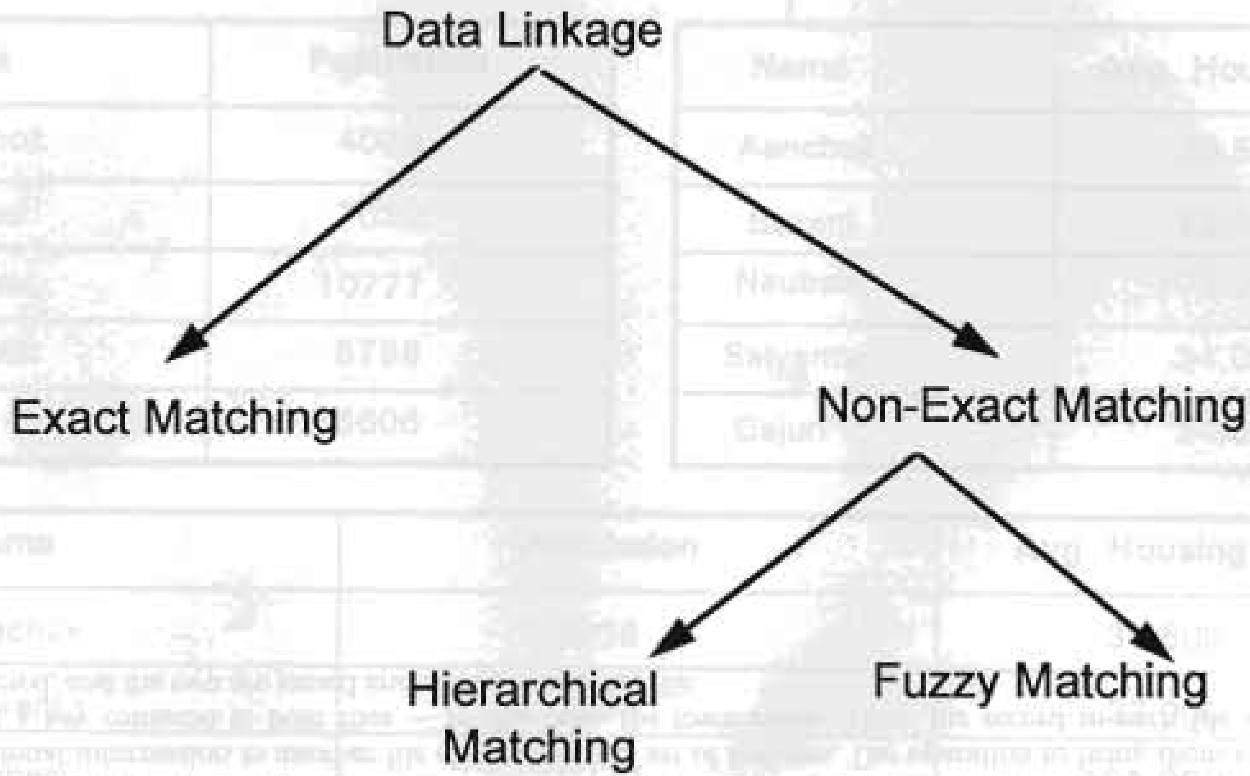
Computer and Spatial Data



Geometry of Spatial Data



Data Linkage



Data Linkage

A GIS typically links different sets. Suppose you want to know the mortality rate due to cancer among children under 10 years of age in each country. If you have one file that contains the number of children in this age group, and another that contains the mortality rate from cancer, you must first combine or link the two data files. Once this is done, you can divide one figure by the other to obtain the desired answer.

Exact Matching

Name	Population
Aenchok	4038
Baireni	7030
Naubesi	10777
Salyantar	5798
Gajuri	5606

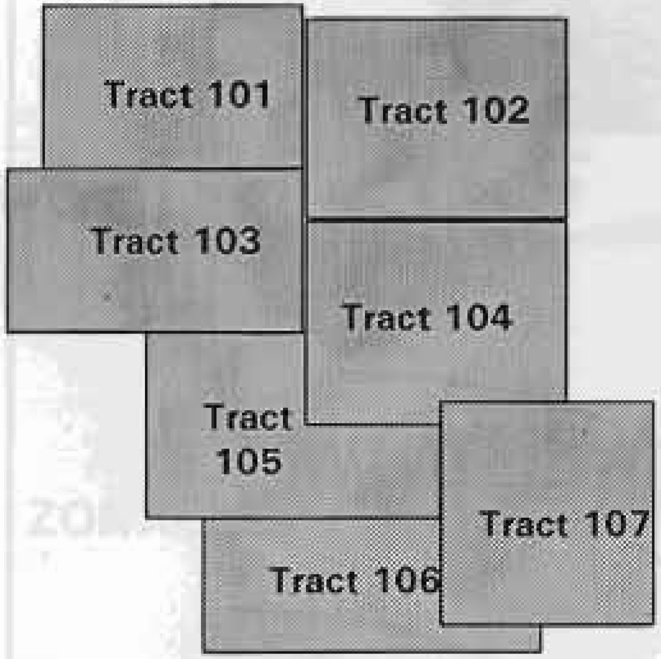
Name	Avg. Housing Cost
Aenchok	30,500
Baireni	22,000
Naubesi	100,000
Salyantar	24,000
Gajuri	24,000

Name	Population	Avg. Housing Cost
Aenchok	4038	30,500
Baireni	7030	22,000
Naubesi	10777	100,000
Salyantar	5798	24,000
Gajuri	5606	24,000

Exact Matching

Exact matching occurs when you have information in one computer file about many geographic features (e.g., towns) and additional information in another file about the same set of features. The operation to bring them together is easily achieved by using a key common to both files — in this case, the town name. Thus, the record in each file with the same town name is extracted, and the two are joined and stored in another file.

Hierarchical Matching



Kathmandu District

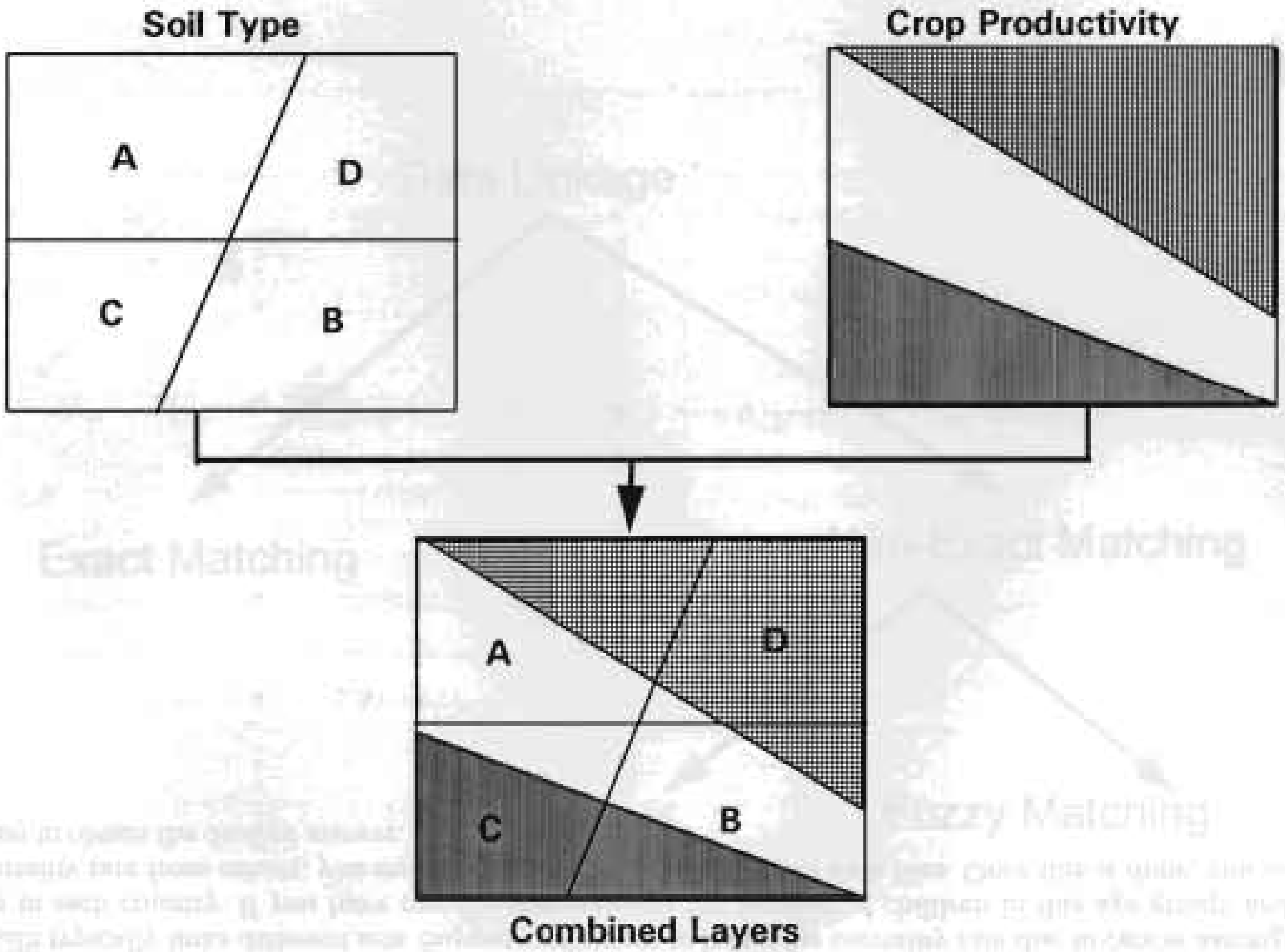
Tract	Town	Population
101	Kathmandu	60,000
102	Maharangung	45,000
103	Patan	35,000
104	Dillibazaar	36,000
105	Baneswor	57,000
106	Nakkhu	25,000
107	Kupondole	58,000

Hierarchical Matching

Some types of information, however, are collected in more detail and less frequently than other types of information. For example, financial and unemployment data covering a large area are collected quite frequently. On the other hand, population data are collected in small areas but at less frequent intervals. If the smaller areas nest (i.e., fit exactly) within the larger ones, then the way to make the data match the same area is to use hierarchical matching — add the data for the small areas together until the grouped areas match the bigger ones and then match them exactly.

The hierarchical structure illustrated in this diagramme shows that this city is composed of several tracts. To obtain meaningful values for the city, the tract values must be added together.

Fuzzy Matching



When data boundaries between layers do not match, the layers can be joined by creating a new layer containing the characteristics of both layers.

Fuzzy Matching

On many occasions, the boundaries of the smaller areas do not match those of the larger ones. This occurs often while dealing with environmental data. For example, crop boundaries, usually defined by field edges, rarely match the boundary between soil types. If you want to determine the most productive soil for a particular crop, you need to overlay the two sets and compute crop productivity for each and every soil type. In principle, this is like laying one map over another and noting the combinations of soil and crop productivity.

A GIS can carry out all of these operations because it uses geography, or space, as a common key between the data sets. Information is linked only if it relates to the same geographical area.

Why is data linkage so important? Consider a situation where you have two data sets for a given area, such as yearly income by county and average cost of housing for the same area. Each data set might be analysed and/or mapped individually. Alternatively, they may be combined. With two data sets, only one valid combination exists. Even if your data set may be meaningful for a single query you will still be able to answer many more questions than if the data sets were kept separate. By bringing them together, you add value to the database. To do this, you need GIS.

LEFT BLANK

Basic Types of Spatial data

Most GIS deal with four (4) types of geographic data: points, lines, areas, and continuous surfaces.

Point data

Points are the simplest type of spatial data. They are zero-dimensional objects with only a position in space but no length.

Line data

Lines (also termed segments or arcs) are one-dimensional spatial objects. Besides having a position in space, they also have a length.

Area data

Areas (also termed polygons) are two-dimensional spatial objects with not only a position in space and a length but also a width (in other words they have an area).

Continuous surface

Continuous surfaces are three-dimensional spatial objects with not only a position in space, a length and a width, but also a depth or height (in other words they have a volume). These spatial objects have not been discussed further because most GIS do not include real volumetric spatial data.

Attribute Handling

District Name	Area	Population
Kathmandu	395 sq. km.	6,75,341
Lalitpur	385 sq. km.	2,57,086
Bhaktapur	119 sq. km.	1,72,952

Attribute data

The attributes refer to the properties of spatial entities. They are often referred to as non-spatial data since they do not in themselves represent location information.

In addition to the spatial representation of a feature, each entity usually has a number of important properties or attributes. These attributes may be nominal (identity, e.g., maize, granite, lake), ordinal (ranking, e.g., class 1, class 2, class 3, and so on), or scalar (value, e.g., water depth, elevation, erosion rate, and so on).

Types of GIS

- Vector GIS
- Raster GIS
- Hybrid GIS

Technology is moving towards hybrid GIS

Raster Vector Integration

Representation of Geographic Data

The representation of geographic data is primarily driven by the types of data structure. This is often termed a data model. A data model is a formal system in which a set of precisely defined objects can be manipulated in accordance with a set of precisely predefined rules, without any regard for the 'meaning' or real-world interpretation of those objects or rules. Reality is an informal system, a system of immense complexity and a system with an infinite amount of information. The difficulty in defining a comprehensive and useful data model is to find a formal system whose behaviour mimics the informal behaviour of the real world as closely as possible

A GIS data model, often known as a geo-relational model, is a formal collection of spatial operators that act on a spatial database in order to relate the user to the real world. GIS uses primarily two spatial data models: **vector and raster**.

Vector and raster models have both advantages and disadvantages. Each approach tends to work best in situations in which the spatial information is to be treated in a manner that closely resembles the data model. For example, the raster model is generally well suited when the geographic information of interest is the spatial variability of a phenomenon; network analysis is best performed with data stored in the vector model.

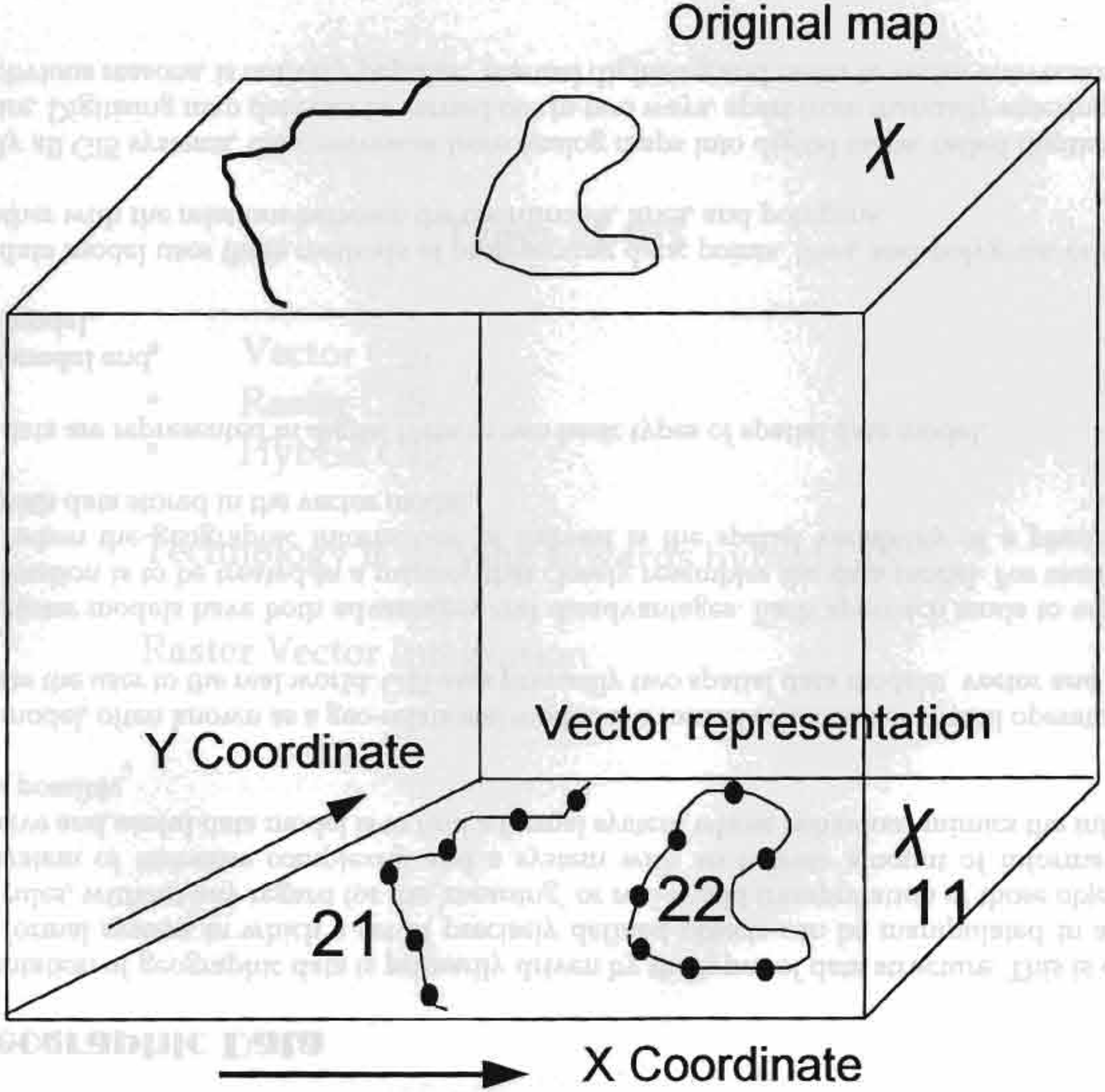
The spatial data are represented in digital form in two basic types of spatial data model.

- **a vector model** and
- **a raster model.**

The vector data model uses three methods of representing data: points, lines, and polygons, of which the x and y coordinates are stored, together with the relations between the coordinates, lines, and polygons.

In practically all GIS systems, the conversion from analog maps into digital maps, called digitising, is carried out using the vector data structure. Digitising map data can be carried out in two ways, apart from manually entering the coordinates via the keyboard, which, for obvious reasons, is not very popular: manual digitising and raster to vector conversion.

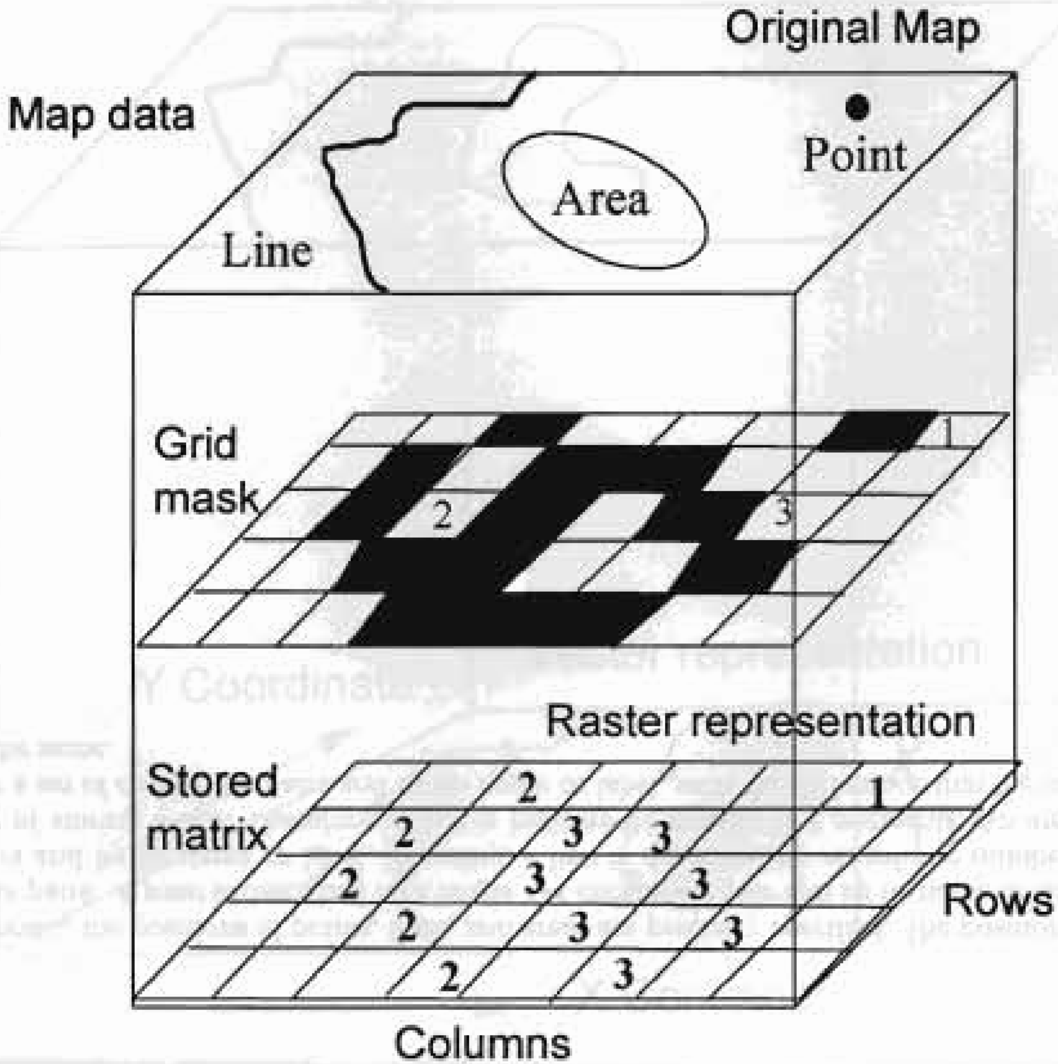
Vector Representation



The vector Model

In a vector model, the positions of points, lines, and areas are precisely specified. The position of each object is defined by a (series of) coordinate pairs. A *point* is described by a single X-Y coordinate pair and by its name or label. A **line** is described by a set of coordinate pairs and by its name or label. In reality, a line is described by an infinite number of points. In practice, this is not a feasible way of storing a line. Therefore, a line is built up of straight line segments. An *area*, also called a *polygon*, as a line is described by a set of coordinate pairs and by its name or label, with the difference that the coordinate pairs at the beginning and the end are the same.

Raster Representation



The raster model

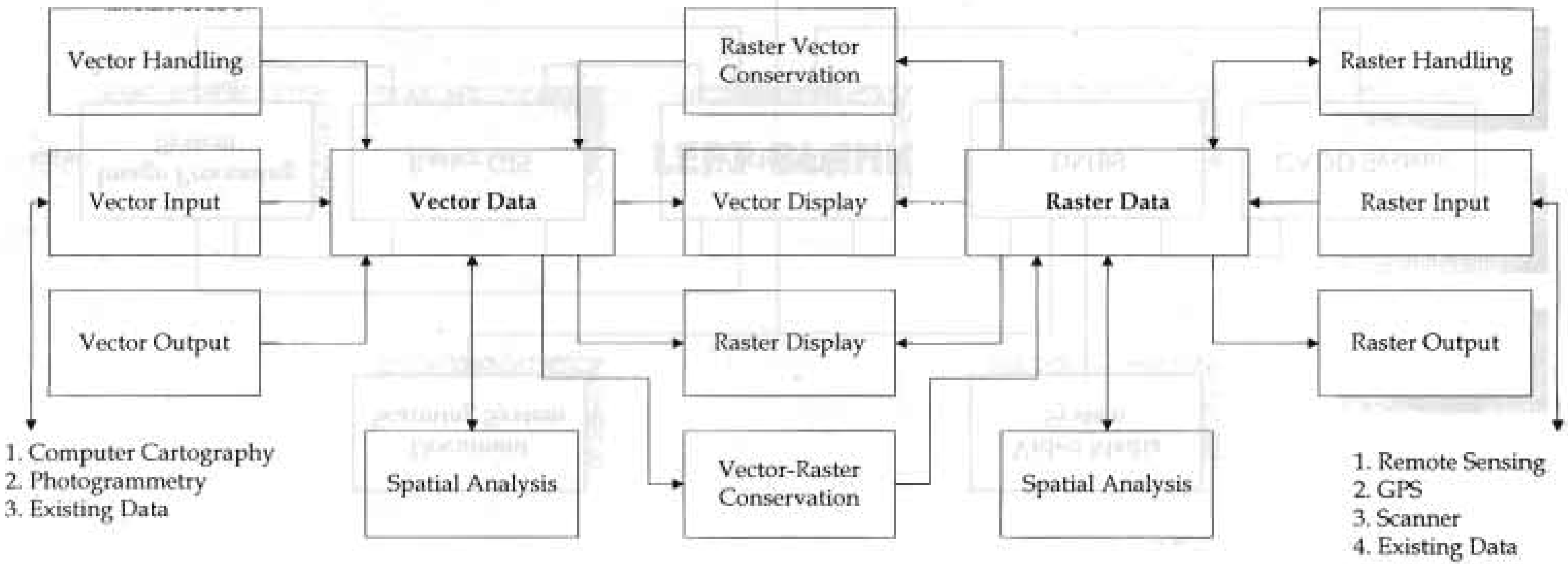
The simplest way of storing spatial data is through the raster model. In this model, the spatial data are organised in cells or pixels (hereafter referred to as pixels). These pixels are the basic units for which information is explicitly recorded. Each pixel is only assigned one value.

A *point* is described by the position of a single pixel. Usually, the position of the cell is defined by a row and column number. A pixel is assigned one numerical value. The name of the point is not explicitly recorded within the pixel itself. A legend has to be available to determine which name belongs to which digital number. A *line* and an *area* are described by a set of connected pixels with one numerical value. In the raster model there is no basic difference in how points, lines, and areas are stored.

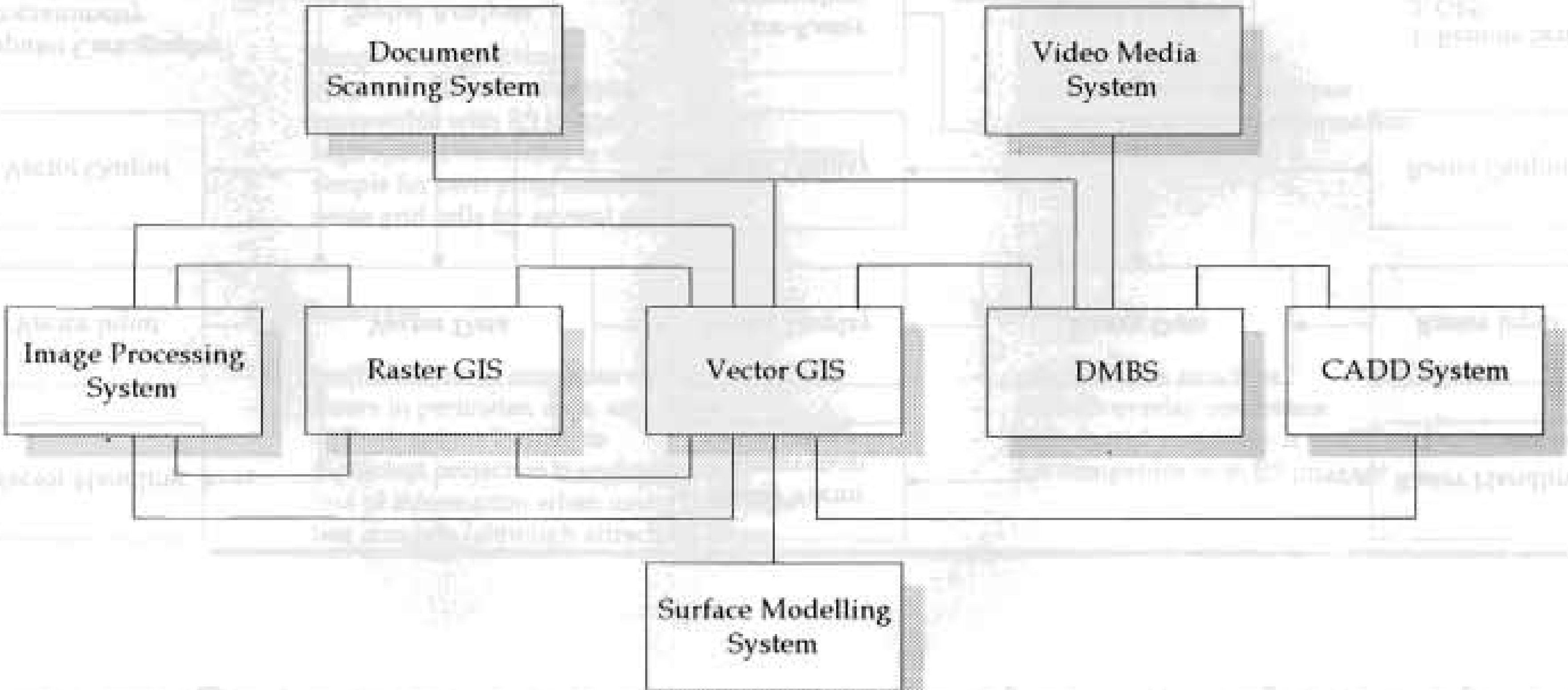
Advantages and Disadvantages of the Raster and Vector Data Models

RASTER MODEL	VECTOR MODEL
Advantages	**Advantages**
- simple data structure	- compact data structure
- easy and efficient overlaying	- efficient for network analysis
- compatible with RS imagery	- efficient projection transformation
- high spatial variability is efficiently represented	- accurate map output
- simple for own programming	
- same grid cells for several attributes	
Disadvantages	**Disadvantages**
- inefficient use of computer storage	- complex data structure
- errors in perimeter, area, and shape	- difficult overlay operations
- difficult network analysis	- high spatial variability is inefficiently represented
- inefficient projection transformations	- not compatible with RS imagery
- loss of information when using large cells	
- less accurate (although attractive) maps	

The Integration of Vector and Raster System - Hybrid System



An Example of Raster and Vector Integration



LEFT BLANK

Four Major GIS Functions

- data capture
  - graphic data: digitised, converted from existing data
  - attribute data: keyed-in, loaded from existing data files

- data storage and manipulation
  - file management
  - editing

- data analysis
  - database query
  - spatial analysis
  - modelling

- data display
  - maps
  - reports

Major Functions of GIS

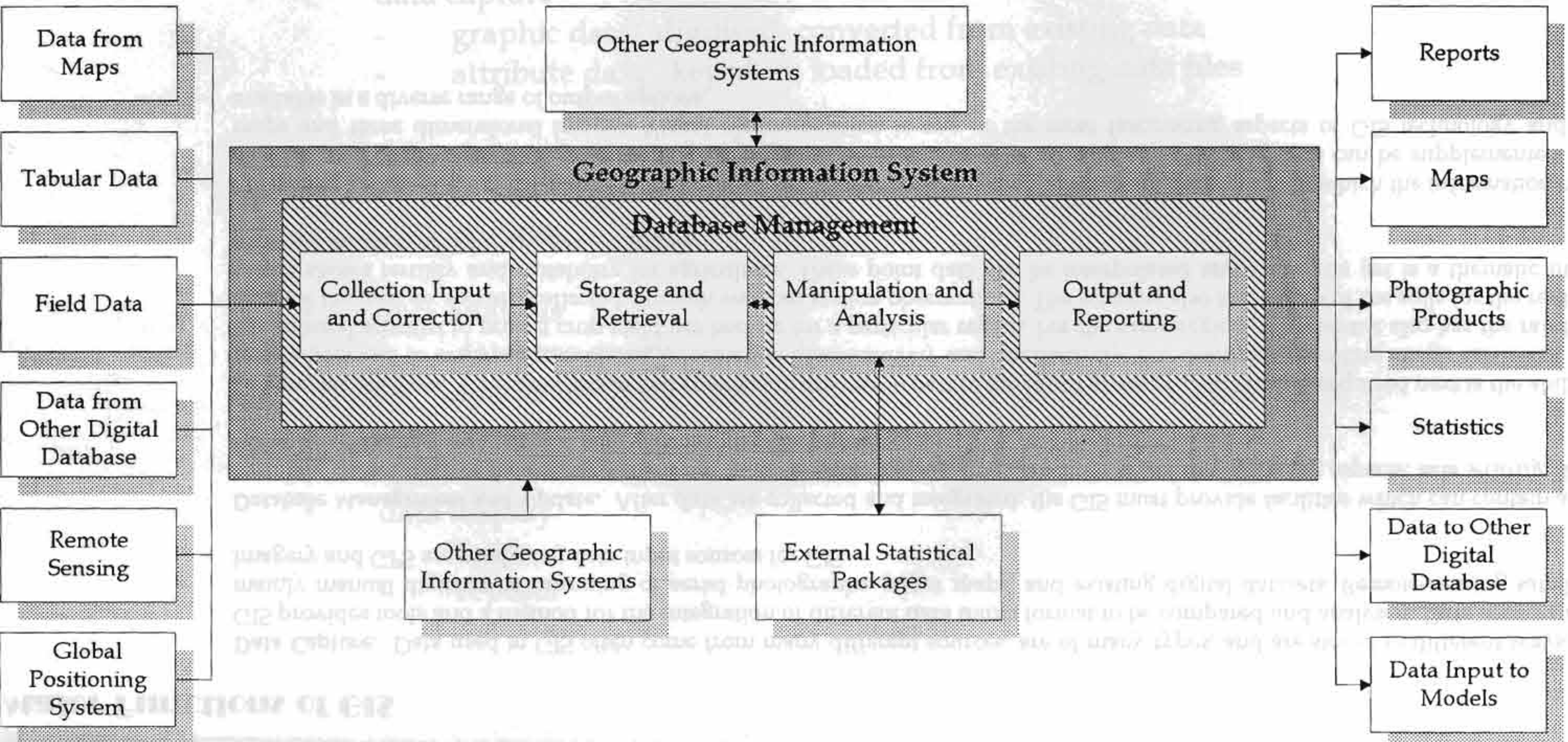
Data Capture. Data used in GIS often come from many different sources, are of many types, and are stored in different ways. A GIS provides tools and a method for the integration of different data into a format to be compared and analysed. Data sources are mainly manual digitisation/scanning of aerial photographs, paper maps, and existing digital datasets. Remote-sensing satellite imagery and GPS are promising data input sources for GIS.

Database Management and Update. After data are collected and integrated, the GIS must provide facilities which can contain and maintain data. Effective data management has many definitions but should include all of the following aspects: *data security, data integrity, data storage* and *retrieval,* and *data maintenance abilities.*

Geographic Analysis. Data integration and conversion are only a part of the input phase of GIS. What is required next is the ability to interpret and to analyse the collected information quantitatively and qualitatively. For example, a satellite image can assist an agricultural scientist to project crop yield per hectare for a particular region. For the same region, the scientist also has the rainfall data for the past six months collected through weather station observations. The scientist also has a map of the soils for the region which shows fertility and suitability for agriculture. These point data can be interpolated and what you get is a thematic map showing isohyets or contour lines of rainfall.

Presenting Results. One of the most exciting aspects of GIS technology is the variety of different ways in which the information can be presented once it has been processed by GIS. Traditional methods of tabulating and graphing data can be supplemented by maps and three dimensional images. Visual communication is one of the most fascinating aspects of GIS technology and is available in a diverse range of output options.

Principal Components and Functions of an Ideal GIS

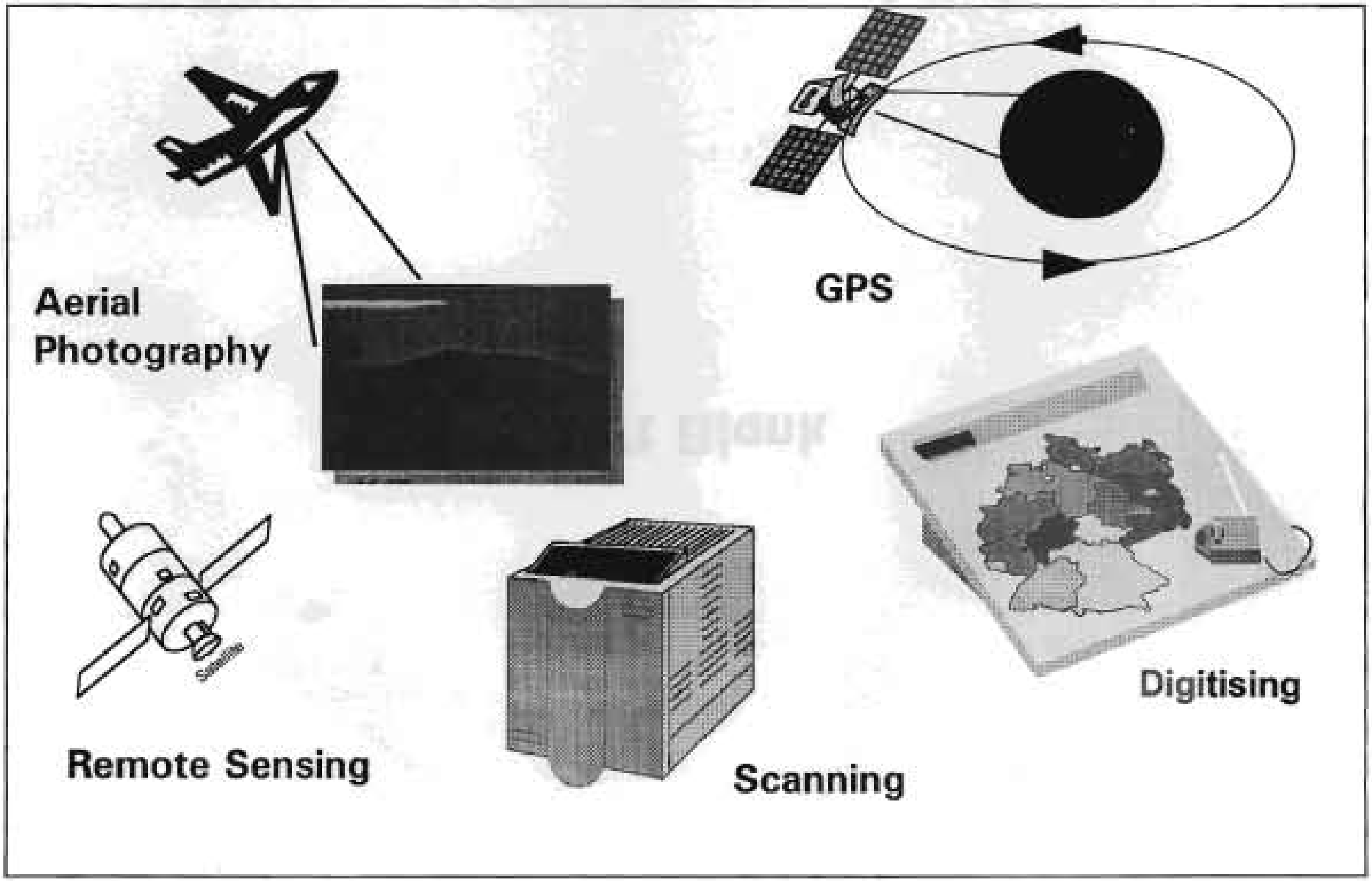


Chapter 3

Data Capture and Database Management

Left Blank

Data Capture

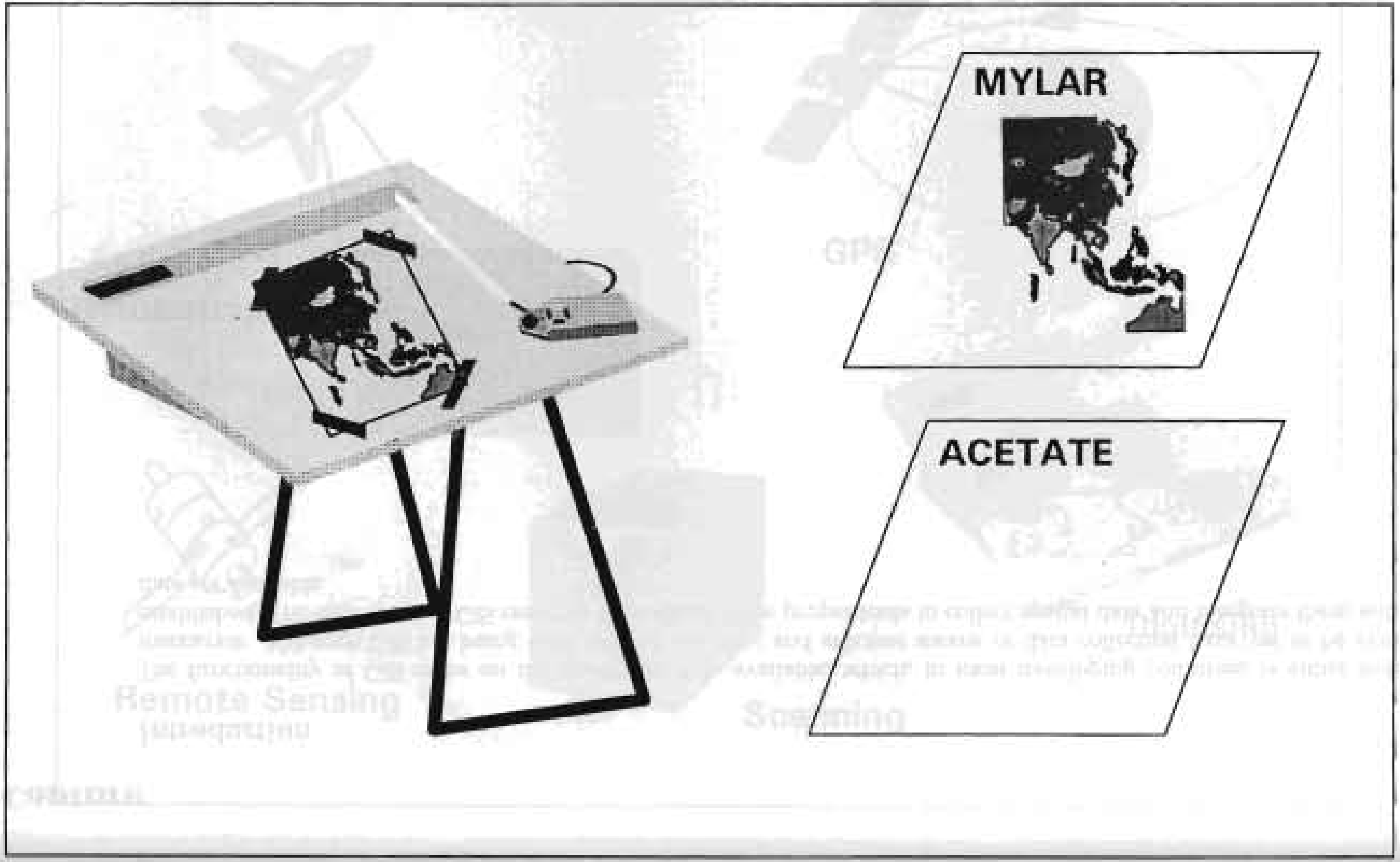


Data Capture

Introduction

The functionality of GIS relies on the quality of data available, which, in most developing countries, is either redundant or inaccurate. Although GIS are being used widely, effective and efficient means of data collection have yet to be systematically established. The true value of GIS can only be realised if the proper tools to collect spatial data and integrate them with attribute data are available.

Manual Digitisation

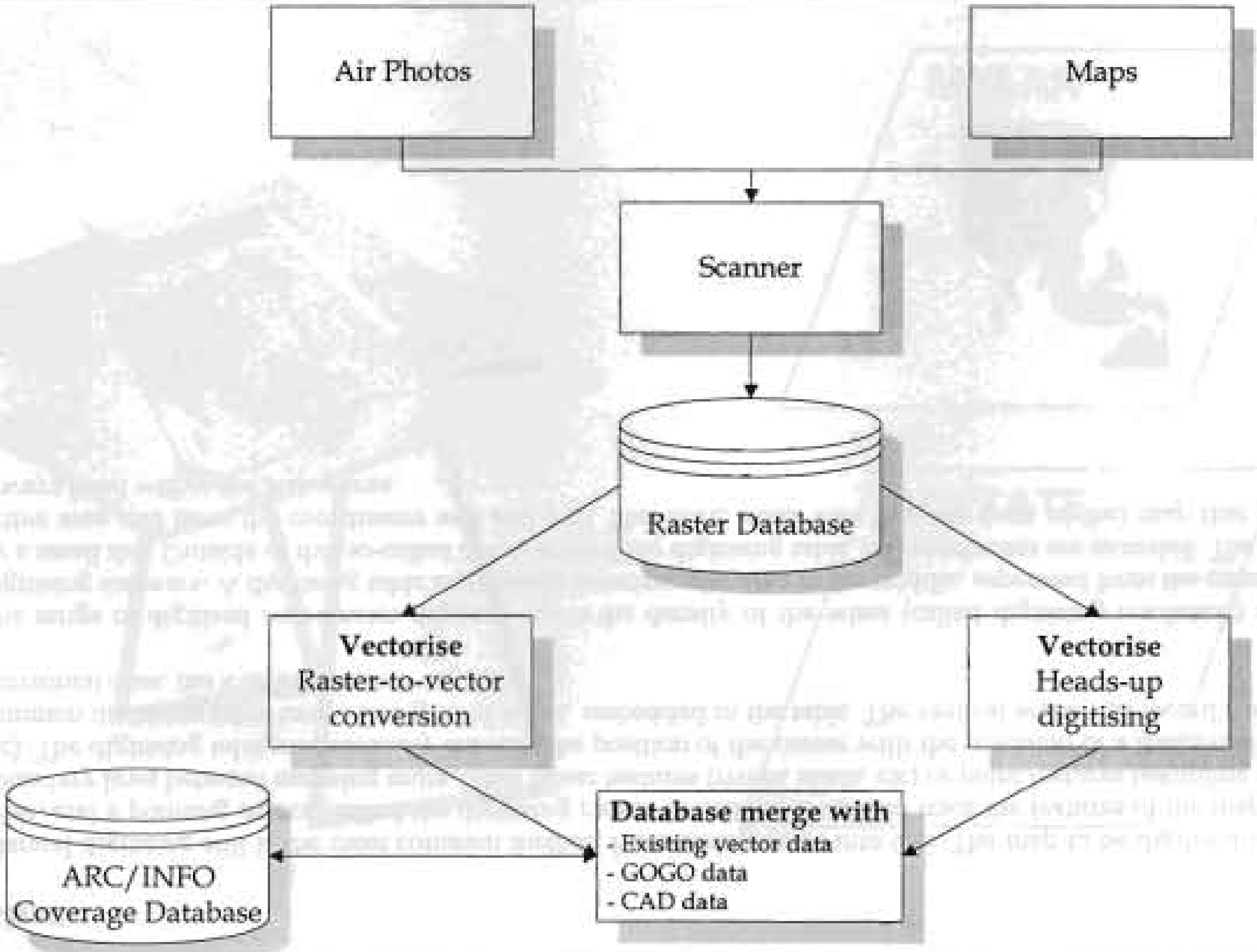


Manual Digitising

Manual digitising still is the most common method for entering maps into GIS. The map to be digitised is affixed to a digitising table, and a pointing device (called the digitising cursor or mouse) is used to trace the features of the map. These features can be boundary lines between mapping units, other linear features (rivers, roads, etc) or point features (sampling points, rainfall stations, etc). The digitising table electronically encodes the position of the cursor with the precision of a fraction of a millimetre. The most common digitising table uses a fine grid of wires, embedded in the table. The vertical wires will record the y coordinates, and the horizontal ones, the x coordinates.

The range of digitised coordinates depends upon the density of the wires (called digitising resolution) and the settings of the digitising software. A digitising table is normally a rectangular area in the middle, separated from the outer boundary of the table by a small rim. Outside of this so-called active area of the digitising table, no coordinates are recorded. The lower left corner of the active area will have the coordinates x=0 and y=0. Therefore, make sure that the (part of the) map that you want to digitise is always fixed within the active area.

Scanning System



Scanning System

The second method of obtaining vector data is with the use of scanners. Scanning (or scan digitising) provides a quicker means of data entry than manual digitising. In scanning, a digital image of the map is produced by moving an electronic detector across the map surface. The output of a scanner is a digital raster image, consisting of a large number of individual cells ordered in rows and columns. For the conversion to vector format, two types of raster image can be used.

- In the case of chloropleth maps or thematic maps, such as geological maps, the individual mapping units can be separated by the scanner according to their different colours or grey tones. The resulting images will be in colour or grey tone images.

- In the case of scanned line maps, such as topographic maps, the result is a black-and-white image. Black lines are converted to a value of 1, and the white areas in between lines will obtain a value of 0 in the scanned image. These images, with only two possibilities (1 or 0) are also called binary images.

The raster image is computer processed to improve the image quality and is then edited and checked by an operator. It is then converted into vector format by special computer programmes which are different for colour/grey tone images and binary images.

Scanning works best with maps that are very clean, simple, relate to one feature only, and do not contain extraneous information, such as text or graphic symbols. For example, a contour map should only contain the contour lines, without height indication, drainage network, or infrastructure. In most cases, such maps will not be available, and should be drawn especially for the purpose of scanning. Scanning and conversion to vector is, therefore, only beneficial in large organisations, where a large number of complex maps are entered. In most cases, however, manual digitising will be the only useful method for entering spatial data in vector format.

Converting Digital Data

•There is no point in digitising if you can find existing data that meet your needs

Key Punching

It is possible in some GIS to input spatial data by keyboard. This involves entering all coordinate pairs of points and lines (for the data in the vector model) or entering values for every pixel (for the data in the raster model). It is not common practice to use the keyboard to enter spatial data, except for entering point data. The main disadvantage is the enormous amount of time it takes to enter all data and also the increased chances for making errors while entering data. For the attribute data, it is normal to make use of the keyboard to enter data.

Data Conversion

While manipulating and analysing data, the same format should be used for all data. This implies that, when different layers are to be used simultaneously, they should all be in vector or all in raster format. Usually the conversion is from vector to raster, because the biggest part of the analysis is done in the raster domain. Vector data are transformed to raster data by overlaying a grid with a user-defined cell size.

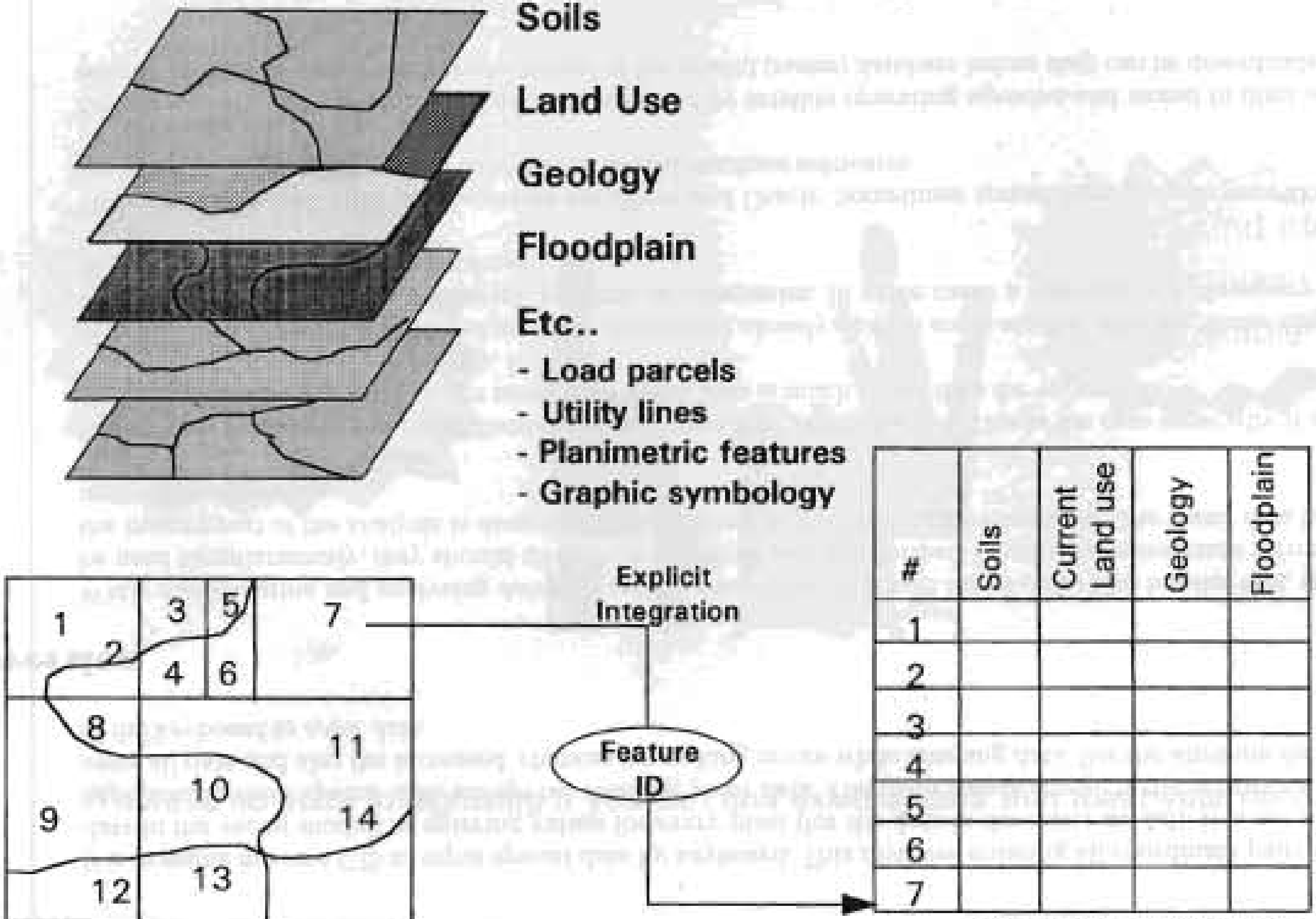
Sometimes the data in the raster format are converted into vector format. This is the case especially if one wants to achieve data reduction because the data storage needed for raster data is much larger than for vector data.

A digital data file with spatial and attribute data might already exist in some way or another. There might be a national database or specific databases from ministries, projects, or companies. In some cases a conversion is necessary before these data can be downloaded into the desired database.

The commonly-used attribute databases are dBase and Oracle. Sometimes spreadsheet programmes like Lotus, Quattro, or Excel are used, although these cannot be regarded as real database softwares.

Remote-sensing images are digital datasets recorded by satellite operating agencies and stored in their own image database. They usually have to be converted into the format of the spatial (raster) database before they can be downloaded.

Spatial Data Management



Topologically Structured Cartographic Data Display and Manipulation

Tabular Data Integration and Manipulation (using a Relational Database Management System)

Geo-Relational Data Model

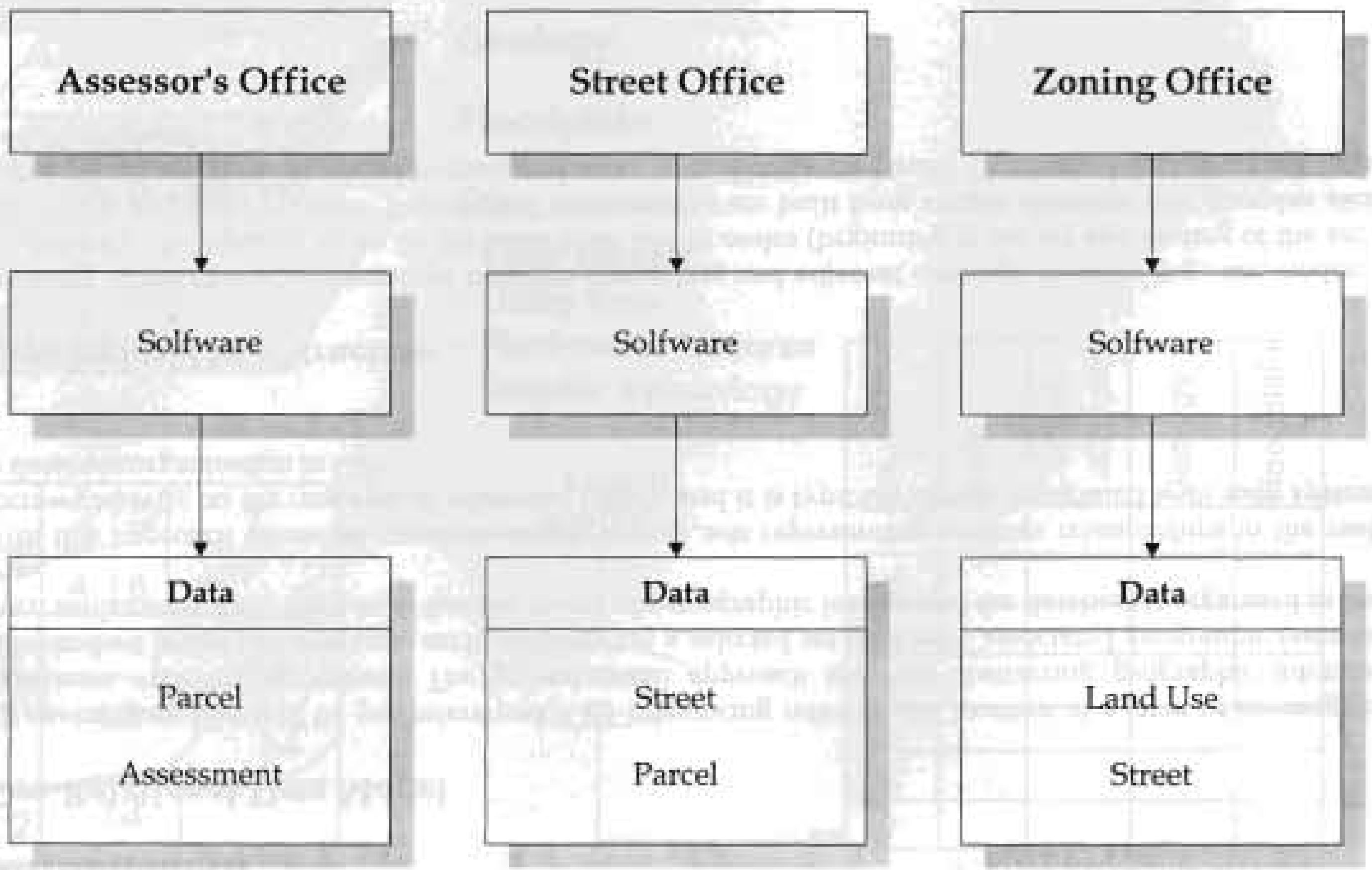
All spatial data files will be geo-referenced. Geo-referencing refers to the location of a layer or coverage in space defined by the coordinate referencing system. The geo-relational approach involves abstracting geographic information into a series of independent layers or coverages, each representing a selected set of closely associated geographic features (e.g., roads, land use, river, settlements, etc). Each layer has the theme of a geographic feature and the database is organised in the thematic layers.

With this approach users can combine simple feature sets representing complex relationships in the real world. This approach borrows heavily on the concepts of relational DBMS, and it is typically closely integrated with such systems. This is fundamental to database organisation in GIS.

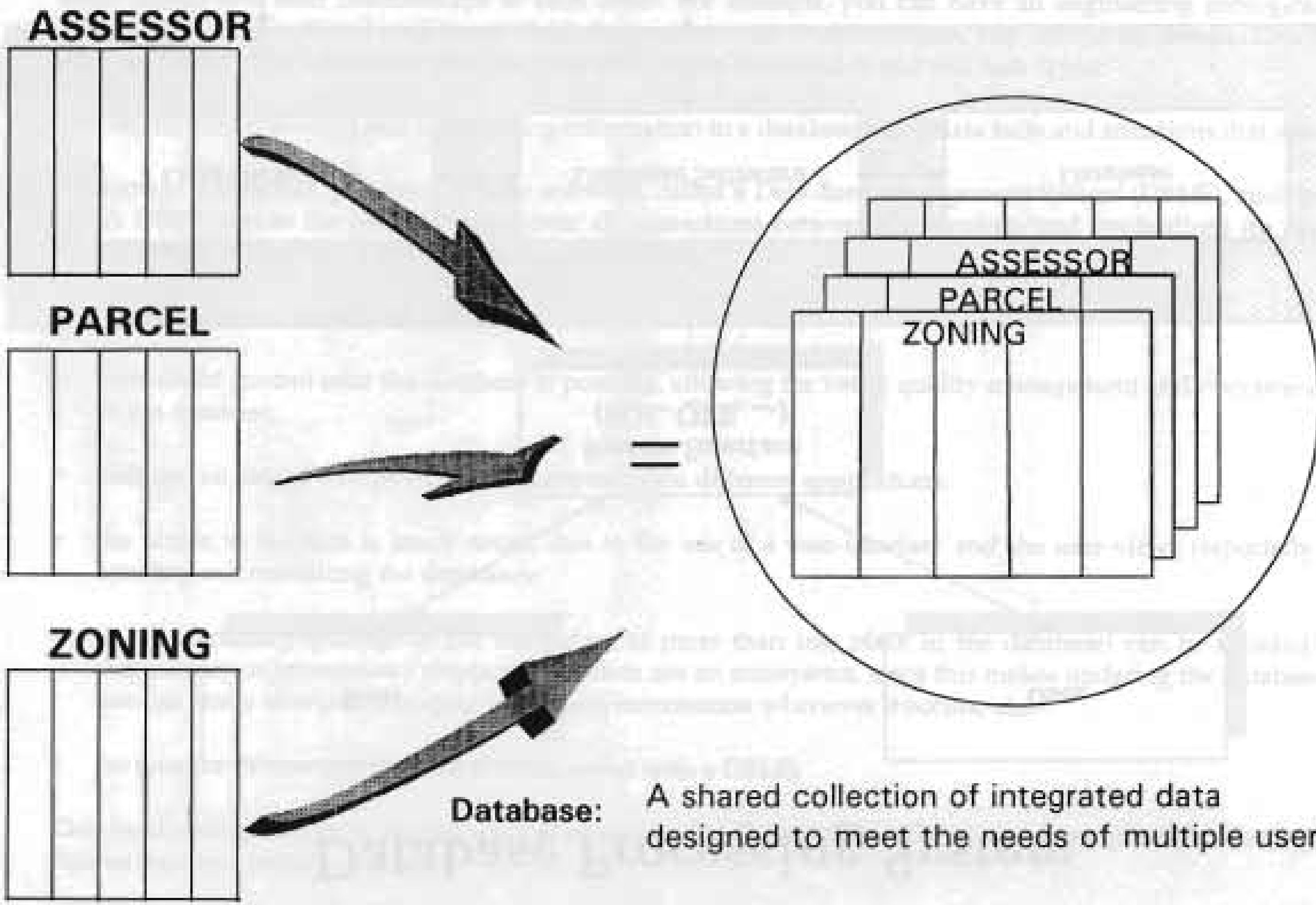
Topological Data Structure

Topology is the spatial relationships between connecting and adjacent coverage features (e.g., arc, nodes, polygons, and points). For instance, the topology of an arc includes from and to nodes (beginning of the arc and ending of the arc representing direction) and its left and right polygon. Topological relationships are built from simple elements into complex elements: points (simplest elements), arcs (sets of connected points), and areas (sets of connected arcs). Topological data structure, in fact, adds intelligence to the GIS database.

Traditional File Operating System

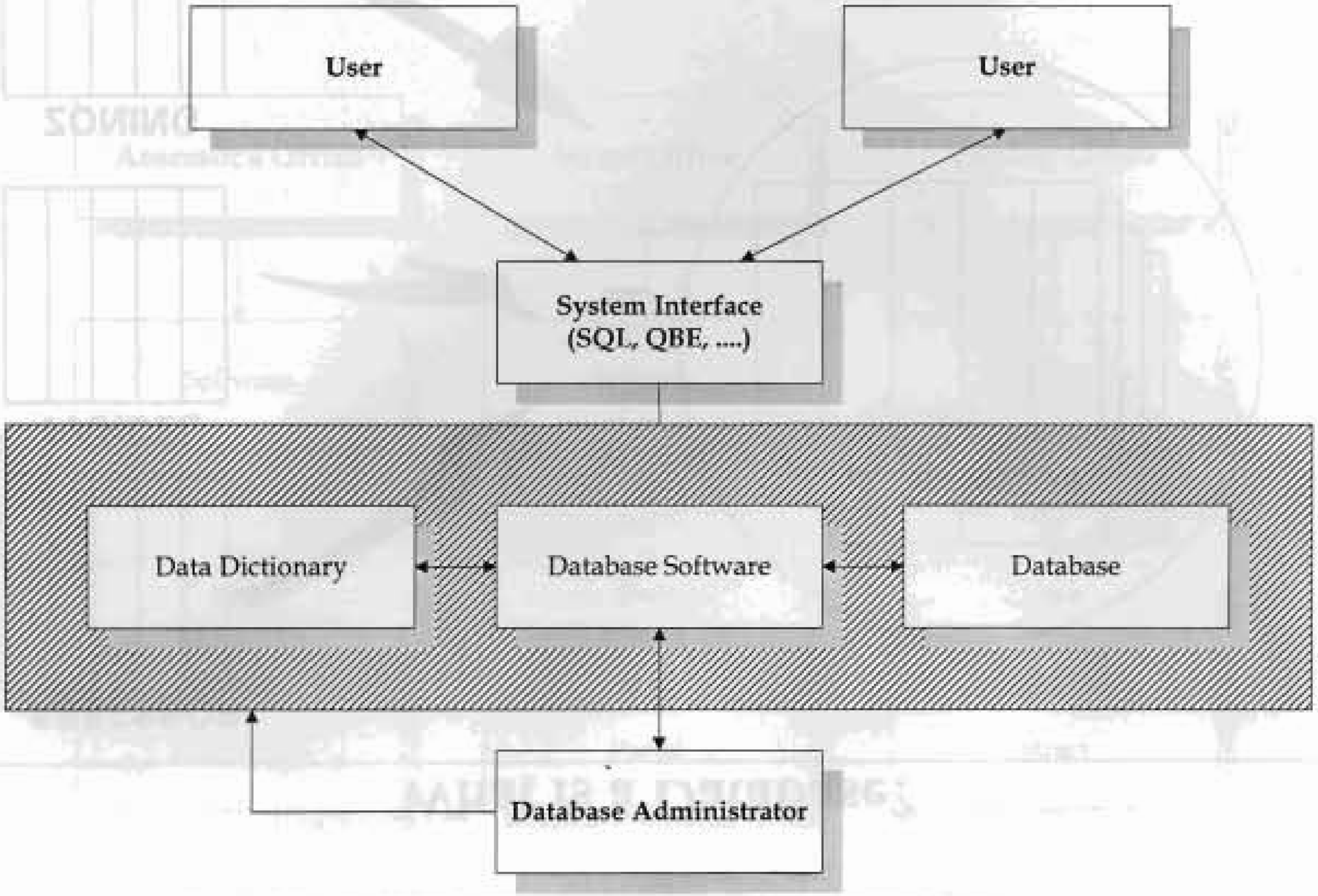


What is a Database?



Database: A shared collection of integrated data designed to meet the needs of multiple users

Database Processing System



Attribute Data Management

All data within a GIS (spatial data, as well as attribute data) are stored within databases. A database is a collection of information about things and their relationships to each other. For example, you can have an engineering geological database, containing information about soil and rock types, field observations and measurements, and laboratory results. This is interesting data, but not very useful if the laboratory data, for example, cannot be related to soil and rock types.

The objective of collecting and maintaining information in a database is to relate facts and situations that were previously separate.

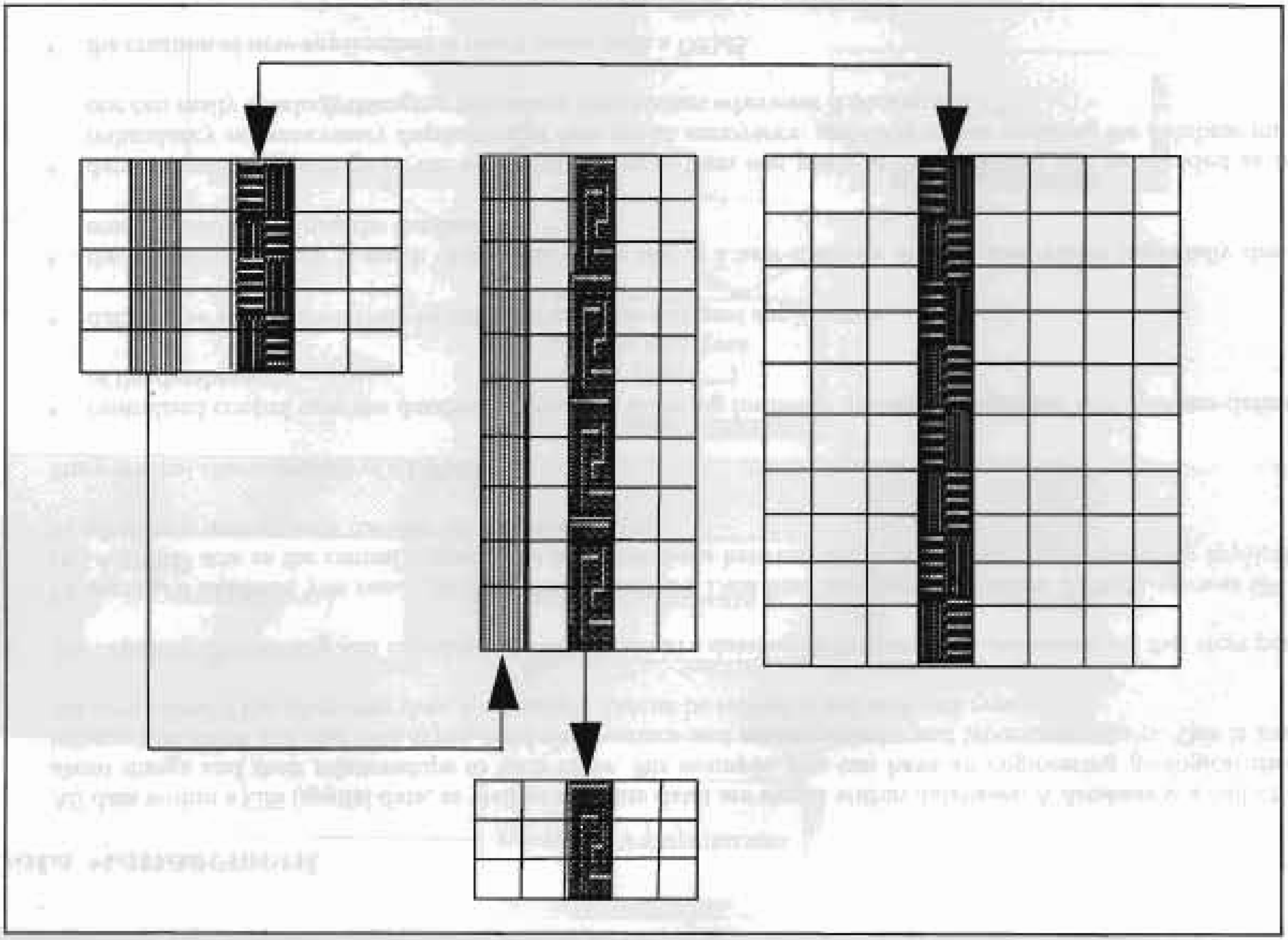
To manage a database, you need specific software, called a Data Base Management System (DBMS), such as ORACLE, DBASEIV, etc. A DBMS acts as the central control over all interactions between the database and applications (or application programme), which in turn interact with the user via a user-interface.

The principal characteristics of a DBMS are:

- centralised control over the database is possible, allowing for better quality management and operator-defined access to parts of the database;
- data can be shared effectively by different users for different applications;
- the access to the data is much easier, due to the use of a user-interface and the user-views (especially designed formats for entering and consulting the database);
- data redundancy (storage of the same data in more than one place in the database) can be avoided as much as possible; redundancy or unnecessary duplication of data are an annoyance, since this makes updating the database much more difficult; one can easily overlook changing redundant information whenever it occurs; and
- the creation of new applications is much easier with a DBMS.

The disadvantages relate to the higher cost of purchasing the software, the increased complexity of management, and the higher risk, as data are centrally managed.

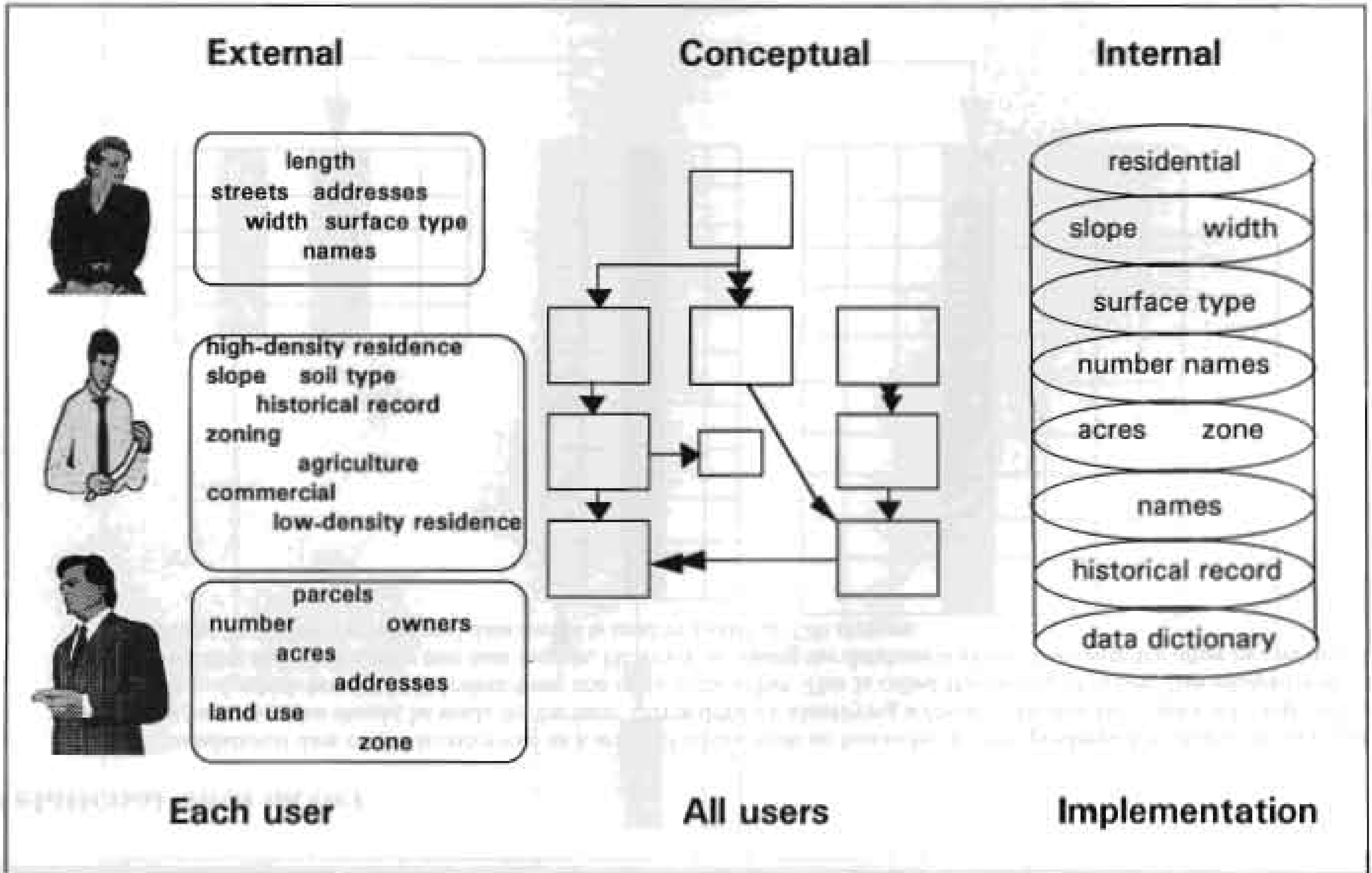
Relational Database



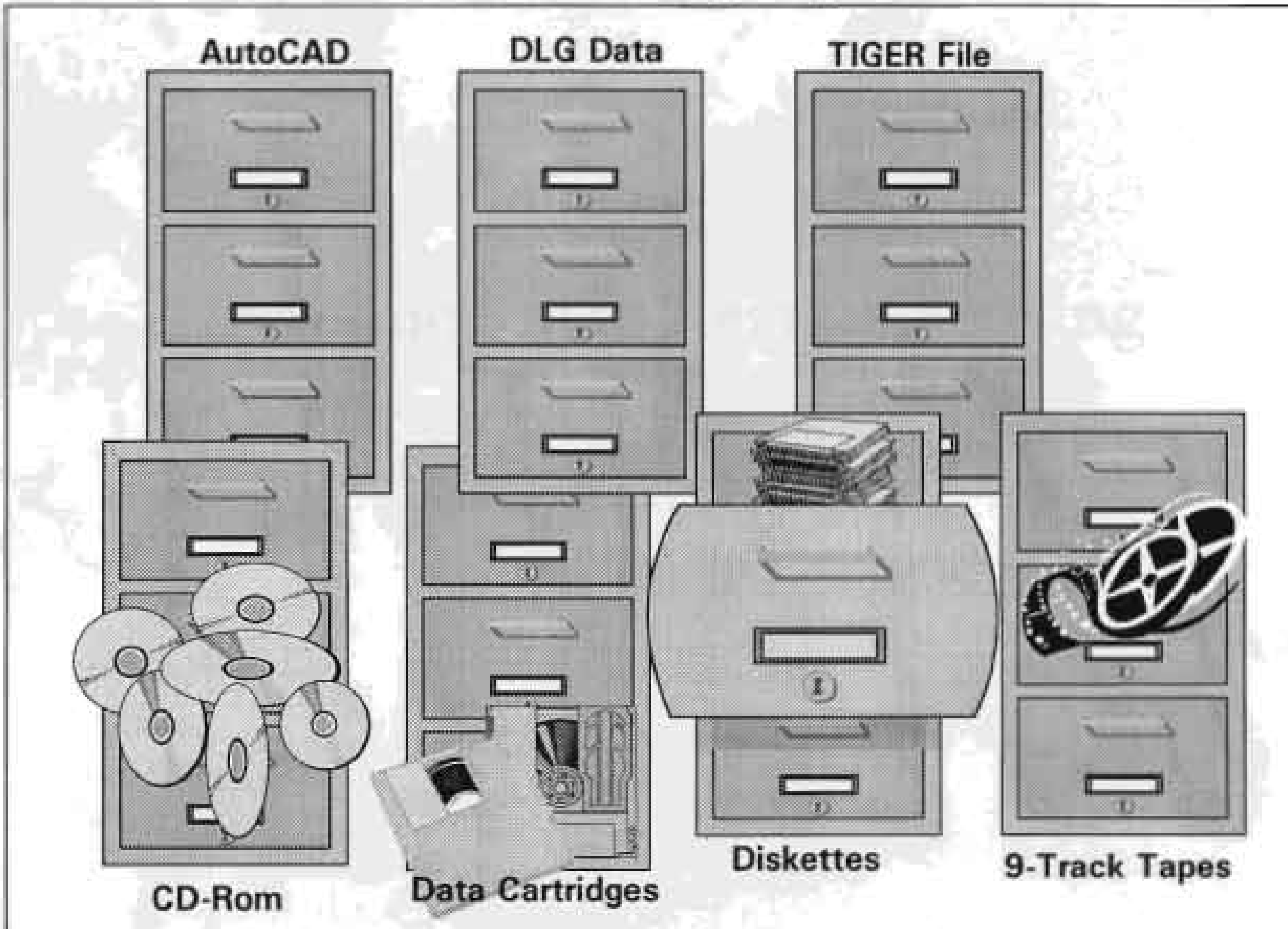
The relational data model

The relational data model is conceived as a series of tables, with no hierarchy nor any predefined relations. The relation between the various tables should be made by the user. This is done by identifying a common field in two tables, which is assigned as the key and which is used to link data from one table to the other. This is called the joining of tables. This allows for much greater flexibility than in the other two data models. However, accessing the database is slower than with the other two models. Due to its greater flexibility, the relational data model is used by nearly all GIS systems.

Database Design Levels

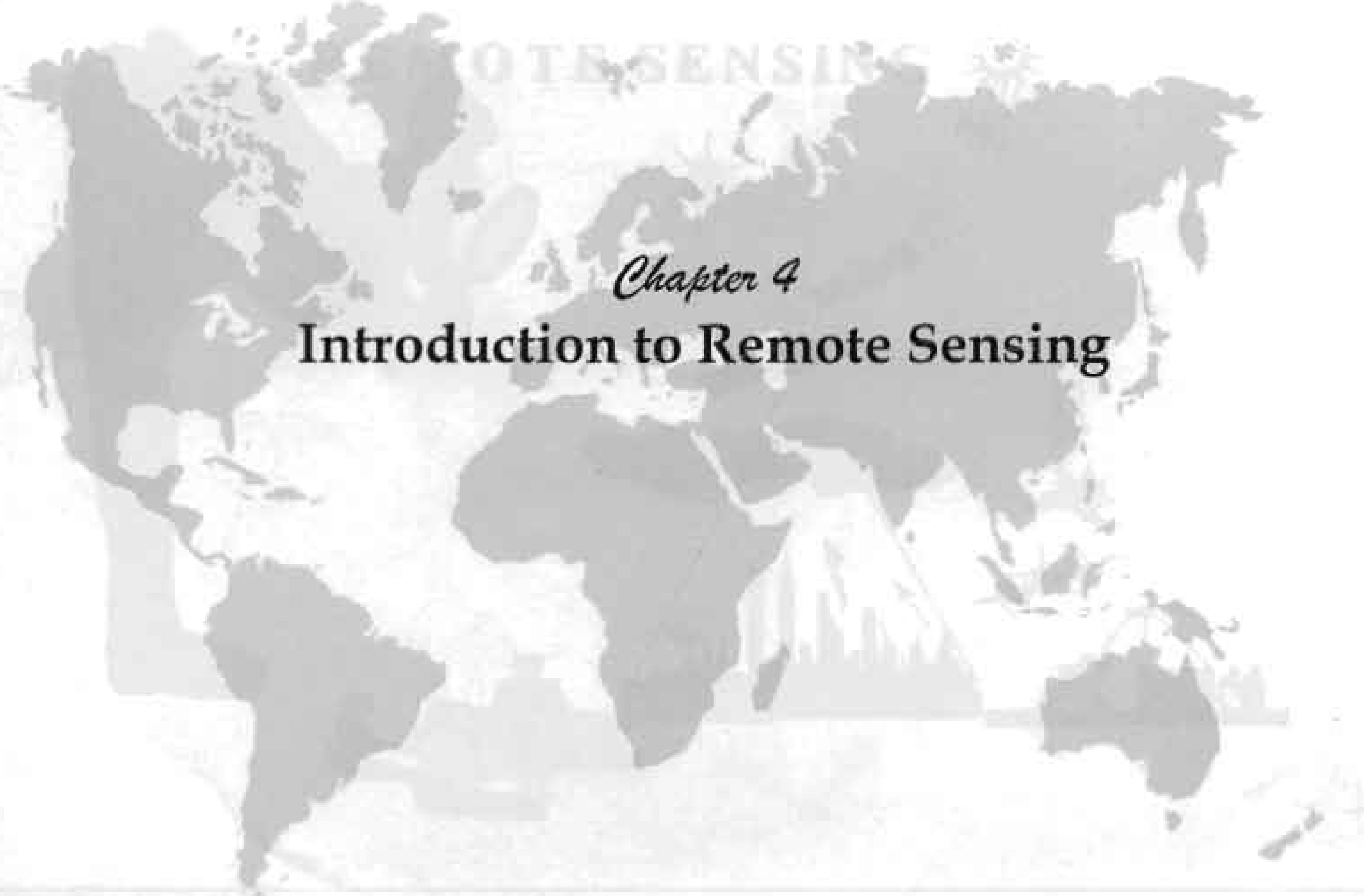


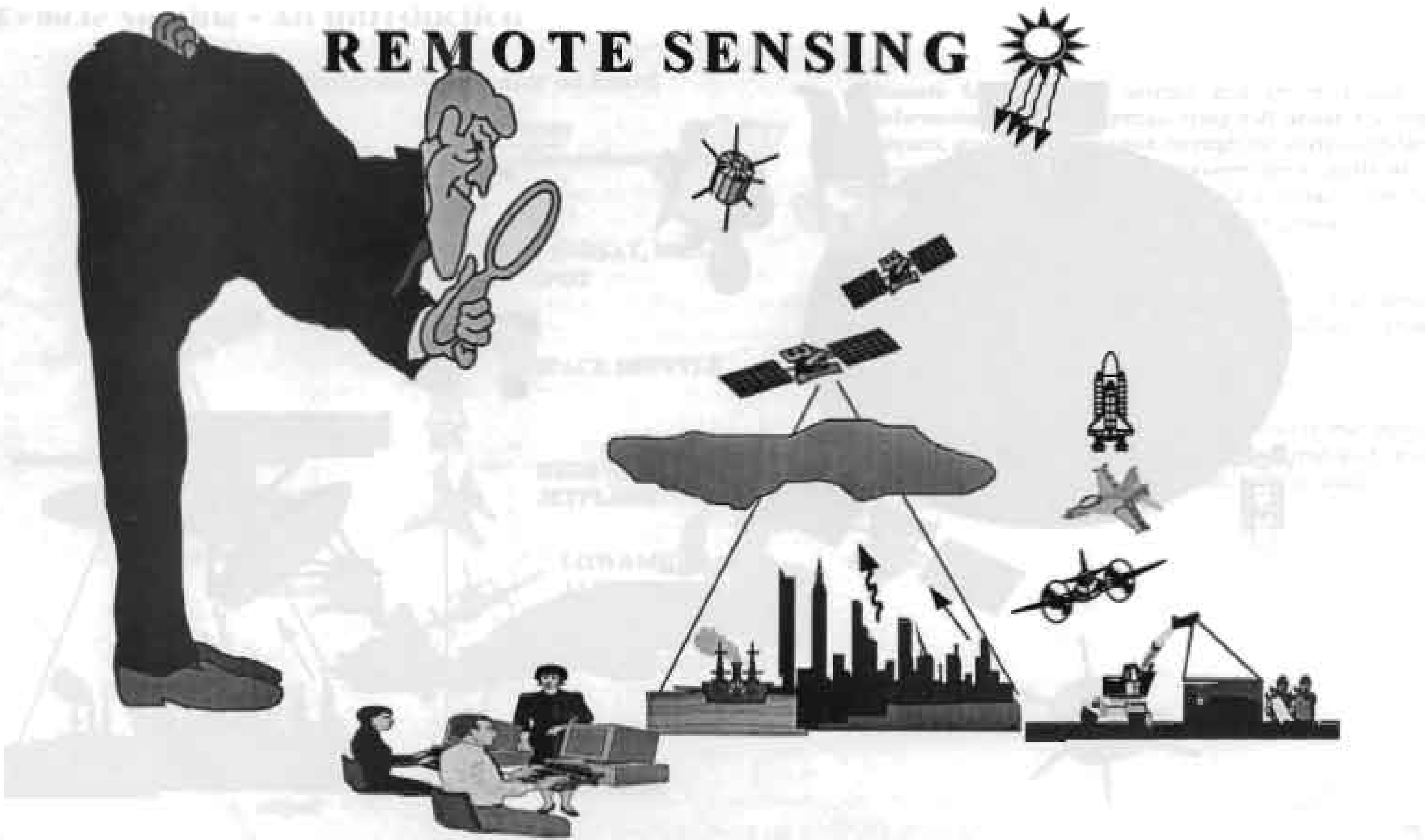
Sources of Existing Digital Data



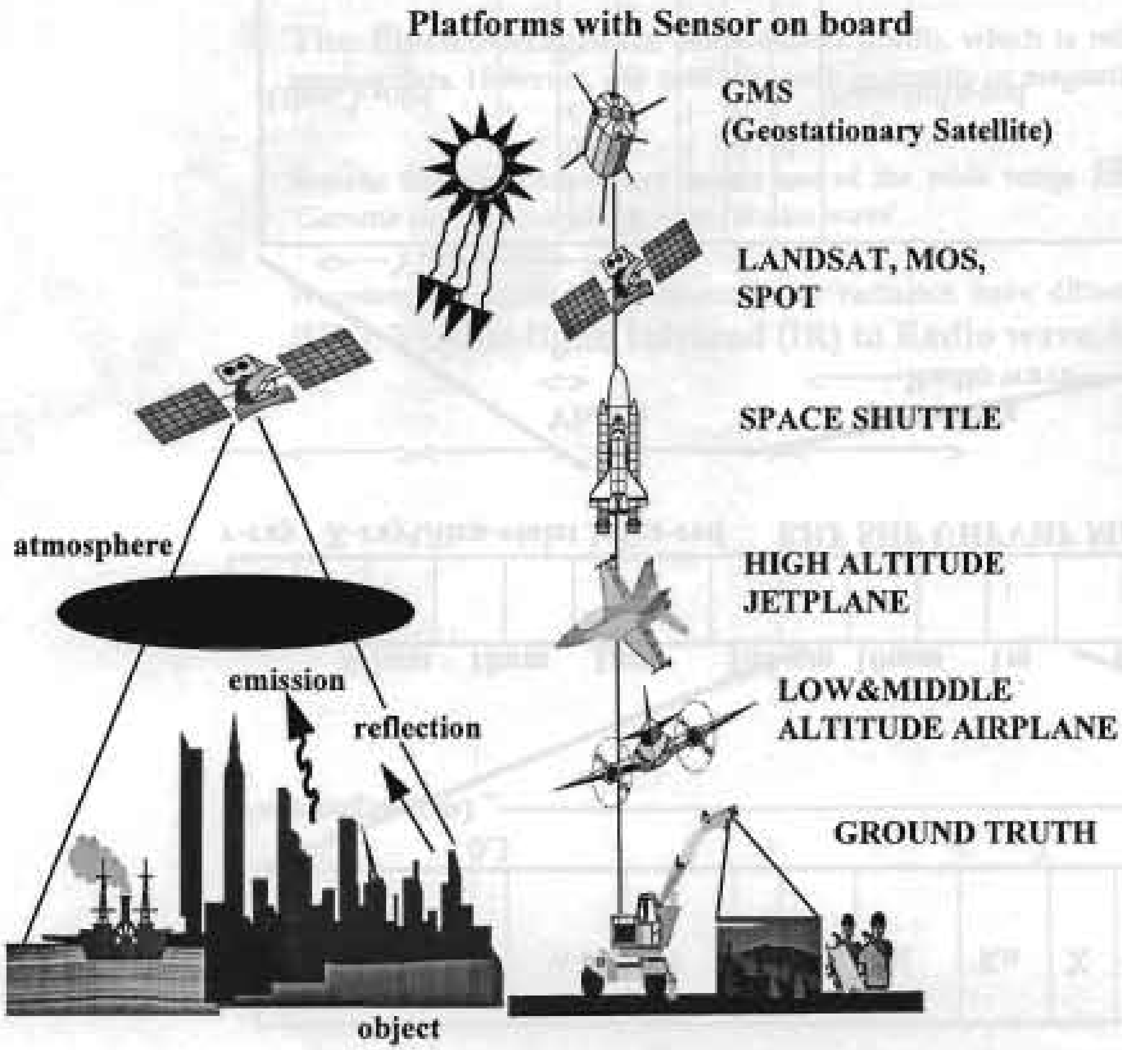
Chapter 4

Introduction to Remote Sensing




REMOTE SENSING

Remote Sensing - An Introduction

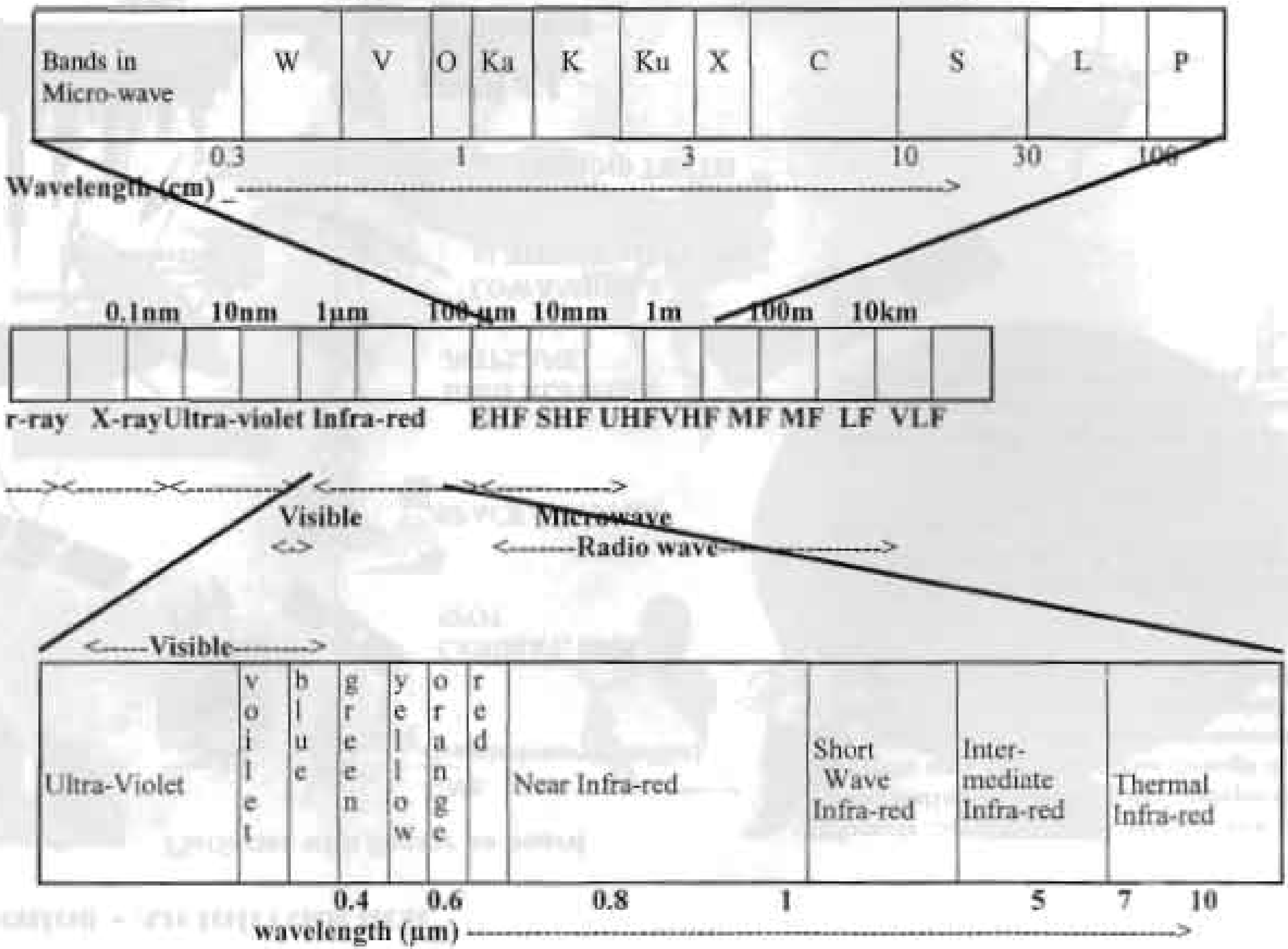


Remote Sensing is the science and art of acquiring information (spectral, spatial, temporal) about material objects, area, or phenomenon through the analysis of data acquired by a device from measurements made at a distance, without coming into physical contact with the objects, area, or phenomena under investigation.

Passive Remote Sensing makes use of sensors that detect the reflected or emitted electro-magnetic radiation from natural sources.

Active Remote Sensing makes use of sensors that detect reflected responses from objects that are irradiated from artificially-generated energy sources, such as radar.

Figure 1: The Bands Used In Remote Sensing



Electro-magnetic Radiation

The Electro-Magnetic Radiation (EMR), which is reflected or emitted from an object, is the usual source of remote-sensing data. However, any medium, such as gravity or magnetic fields, can be used in remote sensing.

Remote Sensing Technology makes use of the wide range **Electro-Magnetic Spectrum** (EMS) from a very short wave 'Gamma ray' to a very long wave 'Radio wave'.

Wavelength regions of electro-magnetic radiation have different names ranging from **Gamma ray, X-ray, Ultraviolet (UV), Visible light, Infrared (IR) to Radio wave**, in order from the shorter wavelengths.

Table 1 : **Classification of Electro-Magnetic Radiation (EMR)**

Class	Wavelength	Frequency
Ultraviolet	100 A - 0.4 µm	750 - 3,000 Thz
Visible	0.4 - 0.7 µm	430 - 750 THz
(Infrared)	0.7 - 1.3 µm	230 - 430 THz
Near Infrared	1.3 - 3µm	100 - 230 THz
Intermediate Infrared	3 - 8µm	38 - 100 THz
Thermal Infrared	8 - 14µm	22 - 38 Thz
Far Infrared	14 µm - 1 mm	0. 3 - 22 THz
(Radio wave) Sub-millimetre	0.1 - 1mm	0.3 - 3 THz
(Radio wave)		
Microwave :		
Millimetre (EHF)	1 - 10 mm	30 - 300 GHz
Centimetre (SHF)	1 - 10 cm	3 - 30 Ghz
Decimeter (UHF)	0.1 -1 m	0.3 - 3 THz
(Radio wave)		
Very Short-Wave (VHF)	1 -10 m	30 -300 MHZ
Short-Wave (HF)	10 - 100 m	3 - 30 MHz
Medium Wave (MF)	0.1 -1 km	0.3 - 3 MHz
Long-wave (LF)	1 - 10 km	30 - 300 kHz
Very Long-wave (VLF)	10 -100 km	3 - 30 kHz

Although names are generally assigned to regions of the electro-magnetic spectrum for convenience (such as ultraviolet and microwave), there is no clear-cut dividing line between one nominal spectral region and the next. Divisions of the spectrum have grown out of the various methods for sensing such types of radiation, more so than from inherent differences in the energy characteristics of various wavelengths. Also, it should be noted that the portions of the electro-magnetic spectrum used in remote sensing lie along a continuum characterised by magnitude chances of many powers of 10. Hence, the use of logarithmic plots to depict the electro-magnetic spectrum is quite common. The 'visible' portion of such plots is extremely small, since the spectral sensitivity of the human eye extends only from about 0.4 μm to approximately 0.7 μm. The color blue is ascribed to the approximate range of 0.4 to 0.5 μm, green to 0.5 to 0.6 μm, and red 0.6 to 0.7 μm. Ultraviolet energy adjoins the blue end of the visible portion of the spectrum. Adjoining the red end of the visible region and three different categories of Infrared (IR) waves; near-IR (from 0.7 to 1.3 μm), short-wave infrared (from 1.3 to 3 μm), intermediate-IR (mid-IR) (from 3 to 8 μm), thermal-IR (from 8 to 14 μm), and far-IR (from 14 μm to 1 mm). At much longer wavelengths of from one mm to 100 km lies the radio wave portion of the spectrum. Within radio waves from one mm to one m is the microwave portion of the spectrum.

Region	Wavelength	Remarks
Gamma Ray	<0.03 nm	Incoming radiation is completely absorbed by the upper atmosphere and is not available for remote sensing.
X-ray	0.03 to 3.0 nm	Completely absorbed by the atmosphere. Not employed in remote sensing.
Ultraviolet	0.03 to 0.4 µm	In-coming wavelengths less than 0.3µm are completely absorbed by ozone in the upper atmosphere.
Photographic UV band	0.3 to 0.4 µm	Transmitted through the atmosphere. Detectable with film and photo-detectors, but atmospheric scattering is severe.
Visible	0.4 to 0.7 µm	Imaged with film and photo-detectors. Includes the reflected energy peak of earth at 0.5µm.
Infrared	0.7 to 100 µm	Interaction with matter varies with wavelength. Atmospheric transmission windows are separated by absorption bands.
Reflected IR band	0.7 to 3.0 µm	Reflected solar radiation that contains no information about thermal properties of materials. The band from 0.7 to 0.9µm is detectable with film and is called the *photographic* IR band.
Thermal IR band	3 to 5 µm 8 to 14µm	Principal atmospheric windows in the thermal region. Images at these wavelengths are acquired by optical-mechanical scanners and special videocon systems, but not by film.
Microwave	0.1 to 30cm	Longer wavelengths can penetrate clouds, fog, and rain. Images may be acquired in the active or passive mode.
Radar	0.1 to 30 cm	Active form of microwave remote sensing. Radar images are acquired at various wavelength bands.
Radio	>30 cm	Longest wavelength portion of the electro-magnetic spectrum. Some classified radar with very long wavelength operate in this region.

Absorption

A process by which radiation is converted to other types of energy (especially heat) by a material.

Emission

In respect to EMR, the process by which a body emits EMR, usually as a consequence of its temperature only.

Incident Ray

A ray impinging on a surface.

Radiation

The emission and propagation of energy through space or through a material medium in the form of waves, for example, the emission and propagation of EM waves, or of sound and elastic waves. The process of emitting radiant energy. Radiance is a measurement of EMR related to the intensity emitted by a source in a given direction.

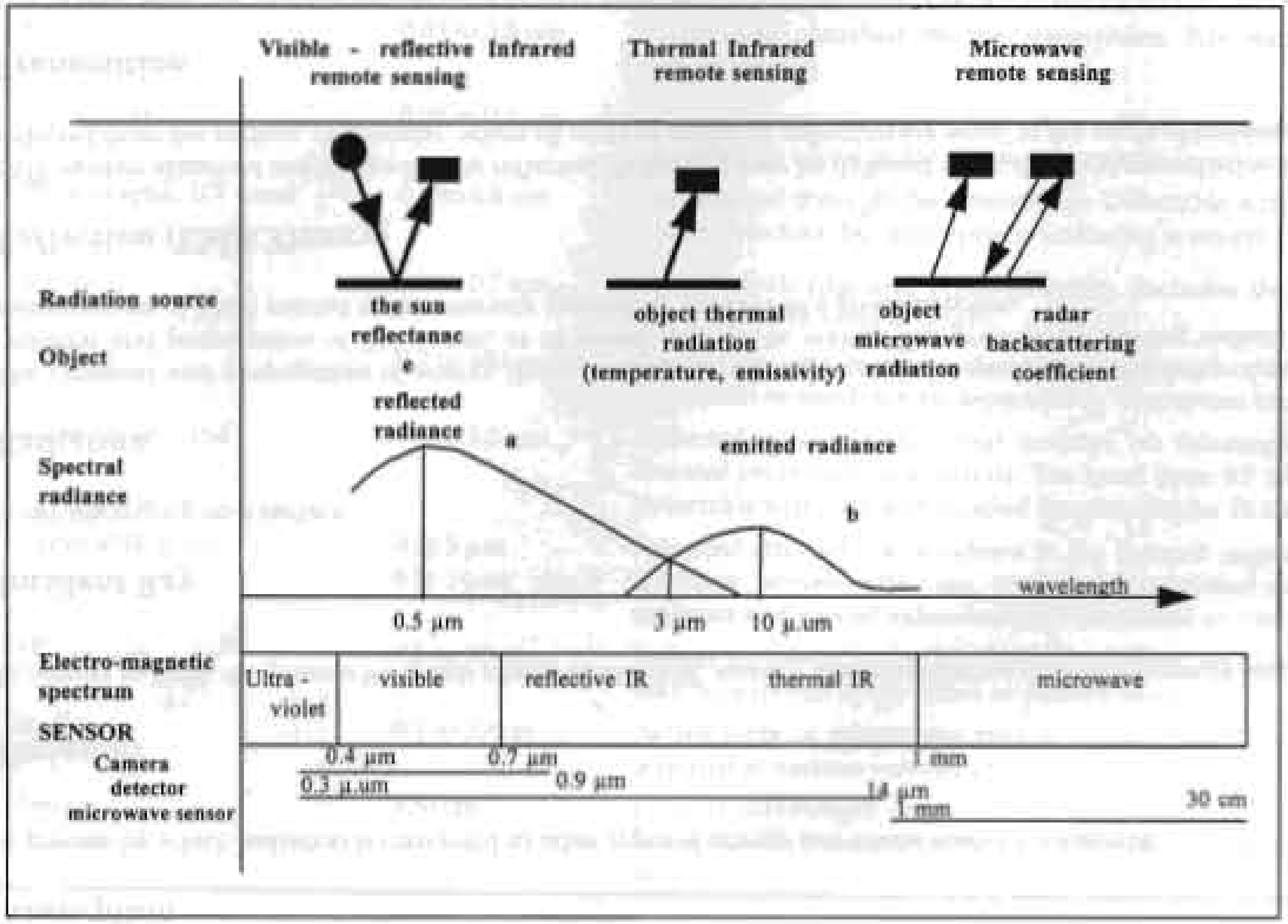
Reflection (EMR Theory)

EMR neither absorbed nor transmitted is reflected. Reflection may be diffused when the incident radiation is scattered upon being reflected from the surface, or specular, when all or most angles of reflection are equal to the angle of incidence.

Transmition

The change from one discrete energy state or level to another as a consequence of absorption or emission of EMR.

Figure 2 : The Three Types Of Remote Sensing In Respect To Wavelength Regions



Types Of Remote Sensing In Respect To Wavelength Regions

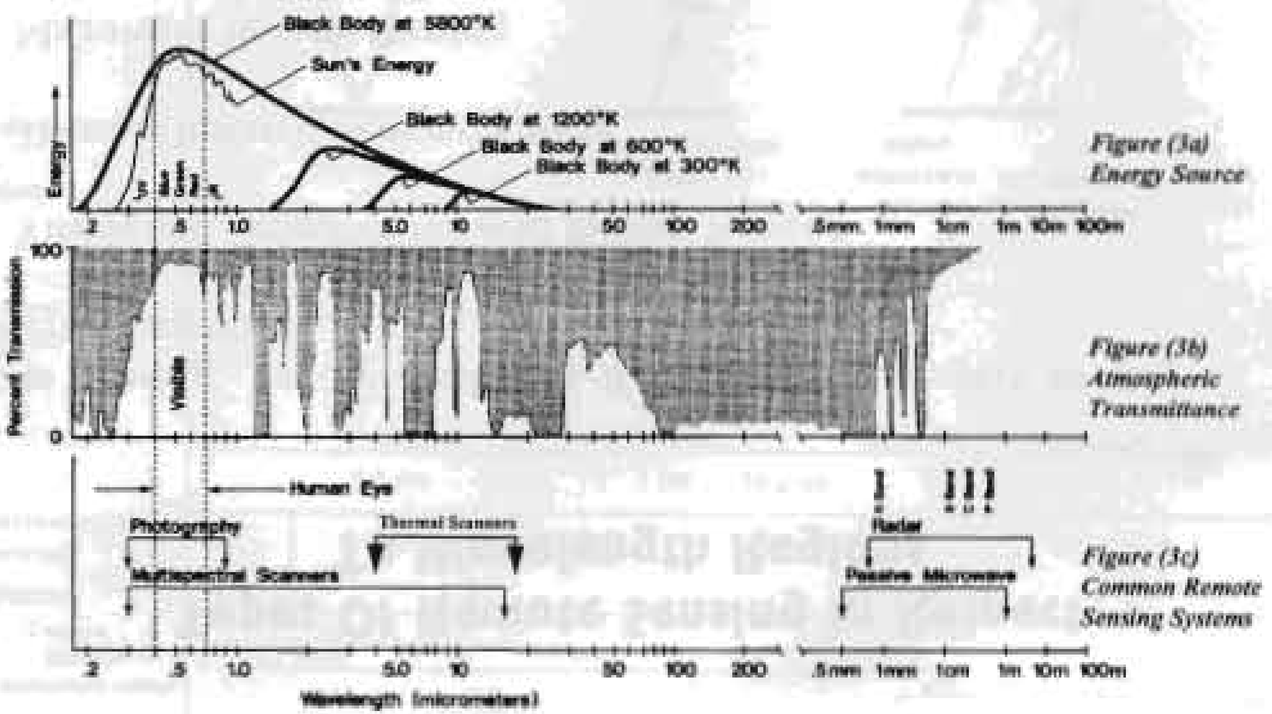
Remote sensing is classified into three types in respect to the wavelength regions

(1) Visible and Reflective Infrared Remote Sensing

(2) Thermal Infrared Remote Sensing

(3) Microwave Remote Sensing

Figure 3: Spectral characteristics of (a) energy source, (b) atmospheric transmittance, (c) remote-sensing systems, (d) example of atmospheric transmission characteristics



Transmittance Of The Atmosphere

The sunlight's transmission through the atmosphere is affected by absorption and scattering of atmospheric molecules and aerosols. This reduction of the sunlight's intensity is called extinction.

The inter-relationship between energy sources and atmospheric absorption characteristics is shown in Figure 3. Figure 3a shows the spectral distribution of the energy emitted by the sun (black body at 5,800° K and by earth features black body at 300° K. These two curves represent the most common sources of energy used in remote sensing. In Figure 3b, spectral regions in which the atmosphere blocks the energy are shaded. Remote-sensing data acquisition is limited to the unblocked spectral regions call atmospheric windows.

Note in Figure 3c that the spectral sensitivity range of the eye (the 'visible' range) coincides both with an 'atmospheric window' and the peak level of energy form the sun. Figure 3d shows the example of atmospheric transmission characteristics and notes some of the important 'atmospheric windows'. An 'atmospheric window' is a portion of the electro-magnetic spectrum in which radiation passing through the atmosphere is not significantly altered by reflection, or absorption, or scattered by the atmospheric constituents. Some useful atmospheric windows are given in Table 2. 'Heat' energy emitted from the earth (black body at 300 K), shown by the small curve in Figure 3a, is sensed through the windows at 3 to 5 μm and 8 to 14 μm using devices such as thermal scanners. Multi-spectral Scanners sense simultaneously through multiple, narrow wavelength ranges that can be located at various points in the visible portion through the thermal spectral region. Radar and passive microwave systems operate through a window in the region one mm to one metre.

The important point to note from Figure 3 is the interaction and the interdependence between the primary sources of electro-magnetic energy, the atmospheric windows through which source energy may be transmitted to and from the earth's surface features, and the spectral sensitivity of the sensors available to detect and record the energy. One can not select the sensor to be used in any given remote-sensing task arbitrarily; one must instead consider (i) the available spectral sensitivity of the sensors, (ii) the presence or absence of atmospheric windows in the spectral range(s) in which one wishes to sense, and (iii) the source, magnitude, and spectral composition of the energy available in these ranges. Ultimately, however, the choice of spectral range of the sensor must be based on the manner in which the energy interacts with the features under investigation. It is to this last, very important, element that we now turn our attention.

Figure 3b: An example of atmospheric transmission characteristics

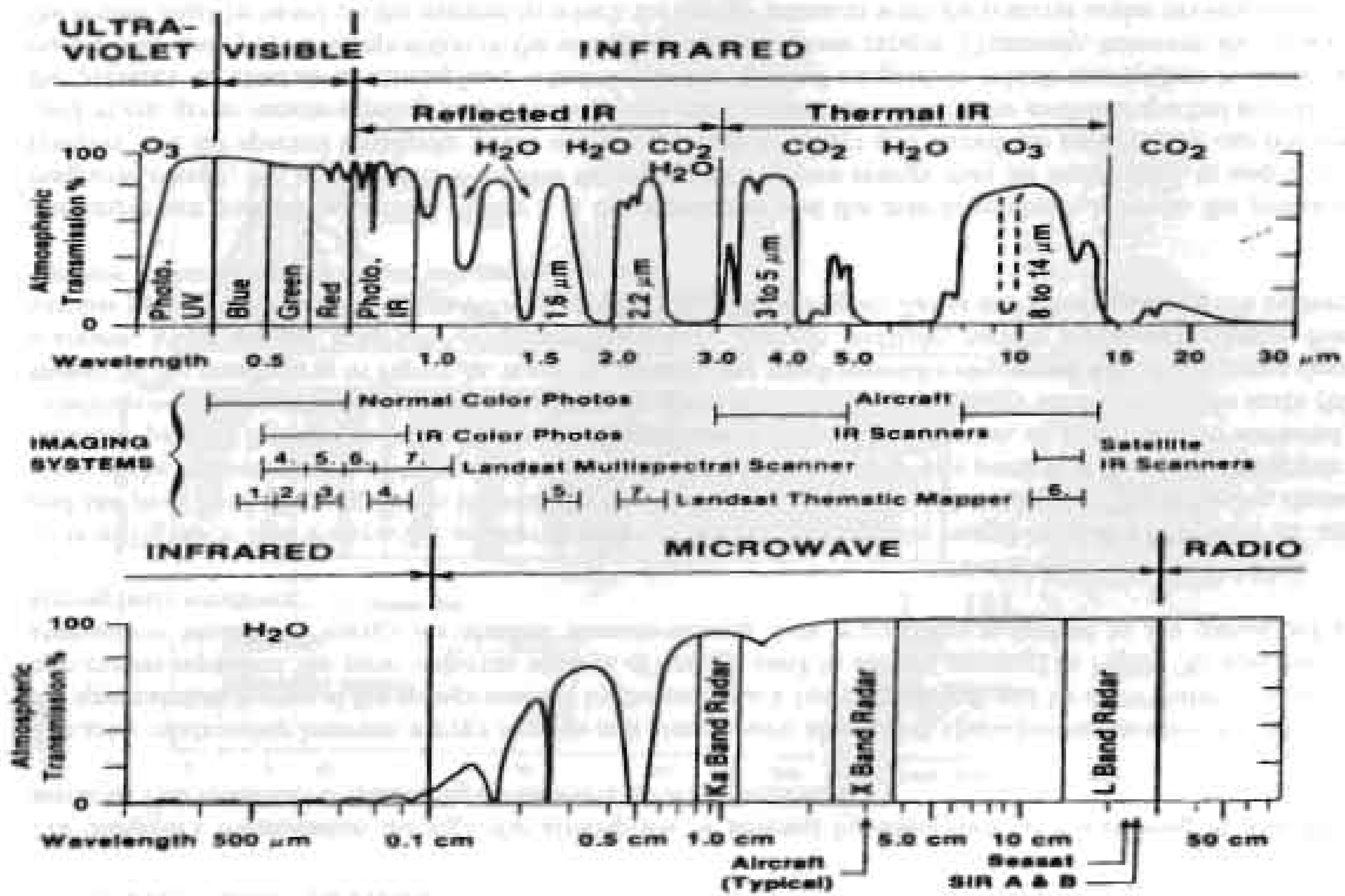
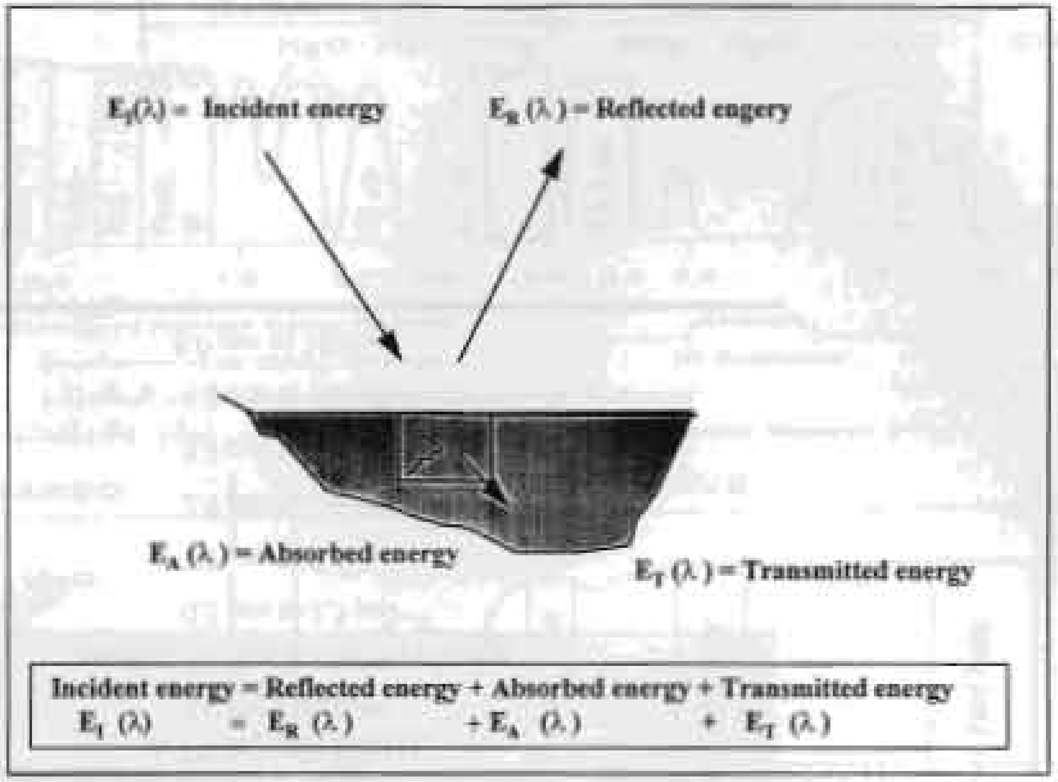


Table 2 : Atmospheric Windows Useful in Remote Sensing

ATMOSPHERIC WINDOWS useful in Remote Sensing
0.3 µm to 1.3 µm
1.5 µm to 1.8 µm
2.0 µm to 2.6 µm
3.0 µm to 3.6 µm
4.2 µm to 5.0 µm
8.0 µm to 14.0 µm

Figure 4 : Basic interactions between electromagnetic energy and an earth surface feature



Interactions between Matter and Electro-Magnetic Radiation

All matter is composed of atoms and molecules with particular compositions. Therefore, matter will emit or absorb electro-magnetic radiation on a particular wavelength with respect to the inner state. All matter reflects, absorbs, penetrates and emits electro-magnetic radiation in a unique way. Electro-magnetic radiation through the atmosphere to and from matters on the earth's surface are reflected, scattered, diffracted, refracted, absorbed, transmitted, and dispersed. For example, the reason why a leaf looks green is that the chlorophyll absorbs blue and red spectra and reflects the green. The unique characteristics of matter are called spectral characteristics.

When electro-magnetic energy is incident on any given earth surface feature, three fundamental energy interactions with the feature are possible. This is illustrated in Figure 4, taking the example of an element of the volume of a water body. Various fractions of the energy incident on the element are **reflected, absorbed**, and/or **transmitted**. Applying the principle of the conservation of energy, we can state the interrelationship between these three energy interactions as shown below.

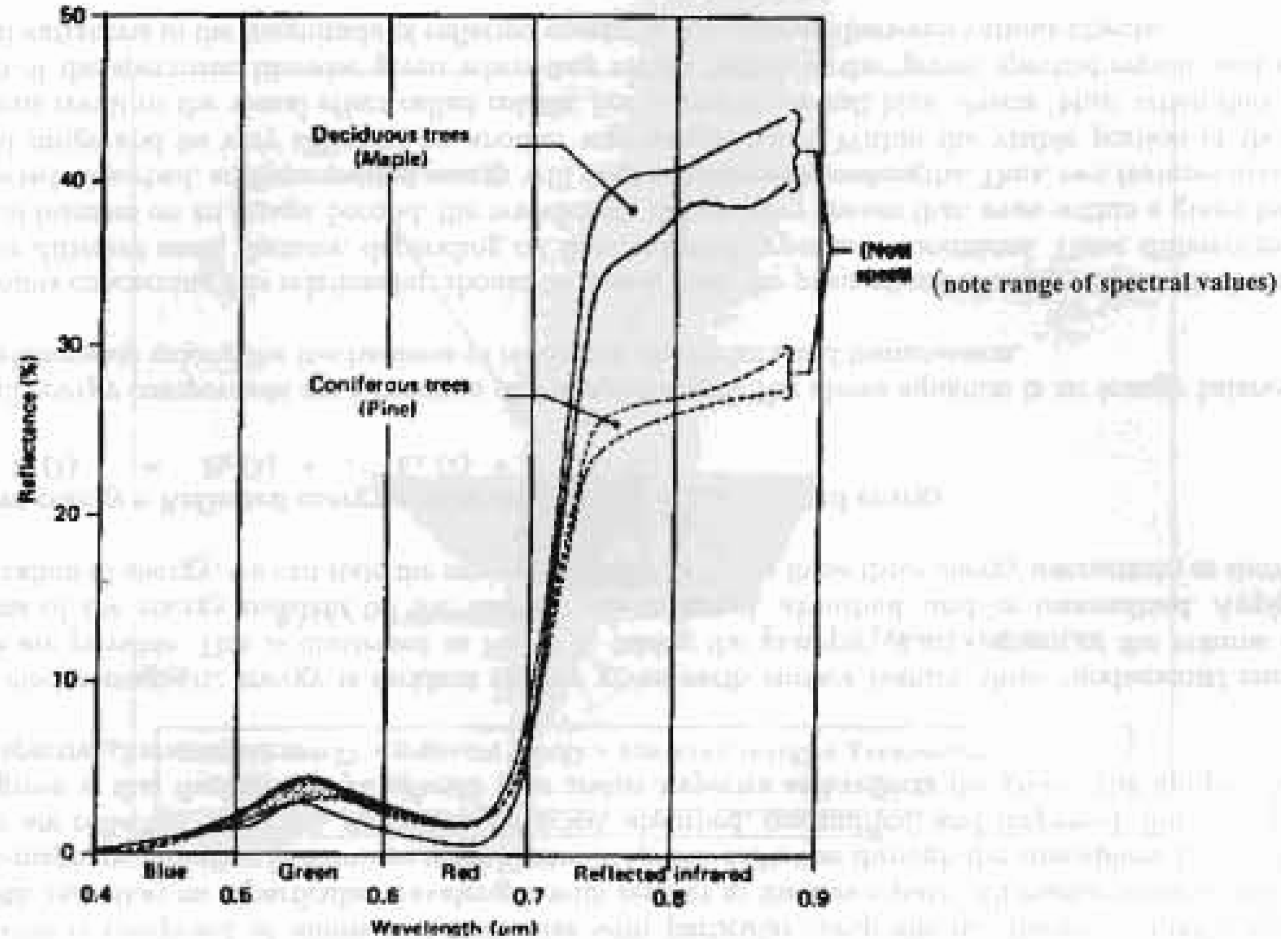
Incident energy = Reflected energy + Absorbed energy + Transmitted energy

$$E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)$$

Here all energy components are a function of the wavelength. The above equation is an energy balance equation expressing the inter-relationship among the mechanisms of reflection, absorption, and transmission.

Two points concerning this relationship should be noted. First, the proportions of energy reflected, absorbed, and transmitted will vary for different earth features, depending on their material types and conditions. These differences permit us to distinguish different features on an image. Second, the wavelength dependency means that, even within a given feature type, the proportion of reflected, absorbed, and transmitted energy will vary at different wavelengths. Thus, two features may be distinguishable in one spectral range and be very different on another wavelength band. Within the visible portion of the spectrum, these spectral variations result in the visual effect called **colour**. For example, we call blue objects 'blue' when they reflect highly in the blue portion of the spectrum, likewise green when they reflect highly in the 'green' spectral region, and so on. Thus, the eye uses spectral variations in the magnitude of reflected energy to discriminate between various objects.

Figure 5 : **Generalised spectral reflectance envelopes for deciduous (broad-leaved) and coniferous (needle-bearing) trees.**



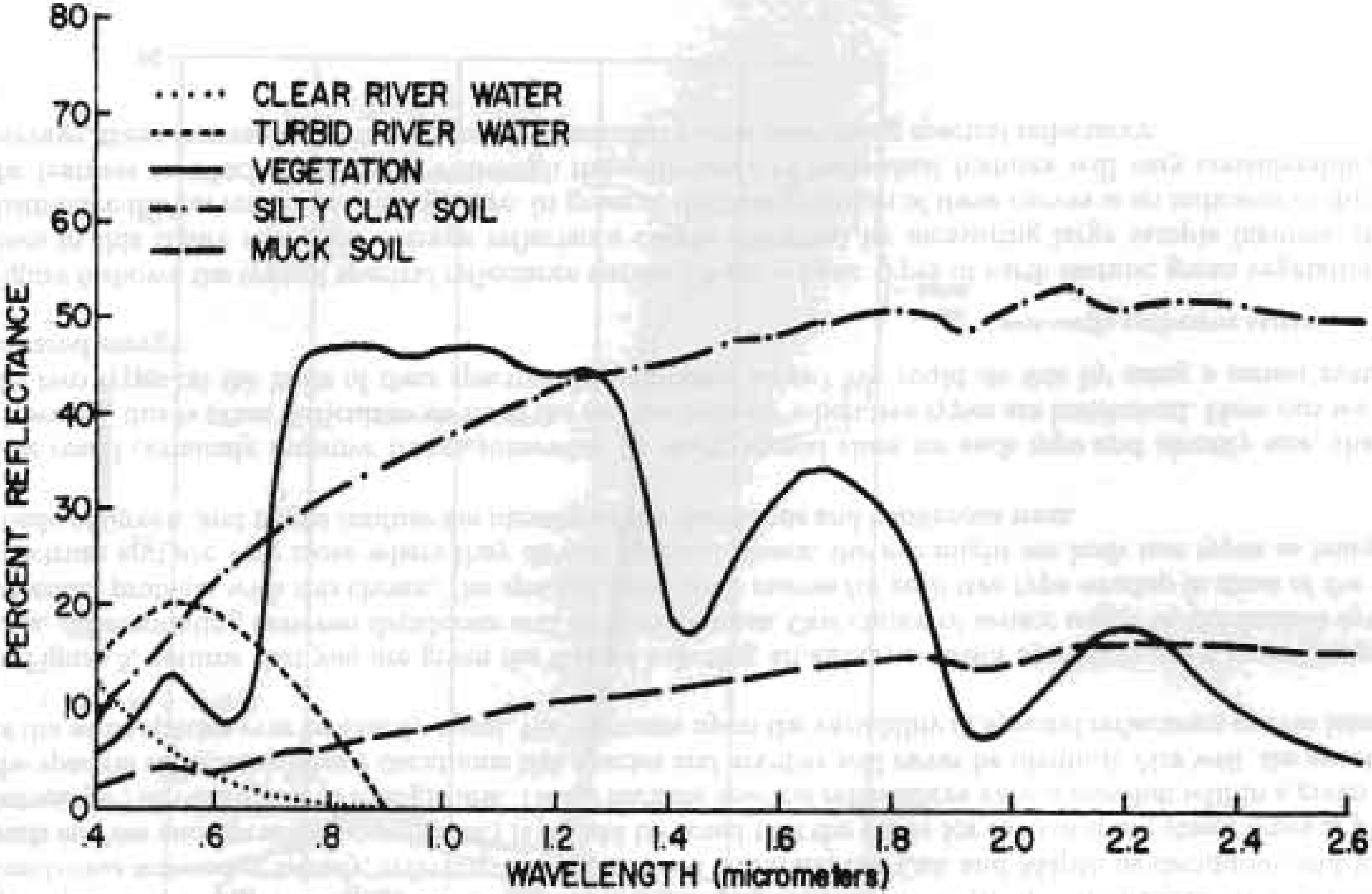
A graph of the spectral reflectance of an object as a function of wavelength is called a spectral reflectance curve. The configuration of spectral reflectance curves provides insight characteristics of an object and has a strong influence on the choice of wavelength region(s) in which remote-sensing data are acquired for a particular application. This is illustrated in Figure 5, which shows highly generalised spectral reflectance curves of deciduous and coniferous trees. (In the discussion, we use the terms deciduous and coniferous somewhat loosely, referring to broad-leaved trees, such as Oak and Maple, as deciduous and to needle-bearing trees, such as Pine and Spruce, as coniferous.) It should be noted that the curve for each of these object types is plotted as a 'ribbon' (or 'envelope') of values, not as a single line. This is because spectral reflectances vary somewhat within a given material class. That is, the spectral reflectance of one deciduous tree species and another will never be identical. Nor will the spectral reflectance of trees of the same species ever be exactly equal. We elaborate upon the variability of spectral reflectance curves later in this section.

In Figure 5, assume that you are given the task of selecting an airborne sensor system to assist in preparing a map of a forested area, differentiating between deciduous and coniferous trees. One choice of sensor might be the human eye. However, there is a potential problem with this choice. The spectral reflectance curves for each tree type overlap in most of the visible portions of the spectrum and are very close where they do not overlap. Hence, the eye might see both tree types as being essentially the same shade of 'green' and might confuse the identity of the deciduous and coniferous trees.

One could certainaly improve things somewhat by using spatial clues for each type and identify size, shape, site, and so forth. However, this is often difficult to do from the air, particularly when tree types are intermixed. How can we discriminate between the two types on the basis of their spectral characteristics alone? We could do this by using a sensor system that records near-infrared energy.

Figure 6 shows the typical spectral reflectance curves for three basic types of earth feature: green vegetation, soil, and water. The lines in this figure represent average reflectance curves compiled by measuring large sample features. It sould be noted how distinctive the curves are for each feature. In general, the configuration of these curves is an indicator of the type and condition of the features to which they apply. Although the reflectance of individual features will vary considerably above and below the average, these curves demonstrate some fundamental points concerning spectral reflectance.

Figure 6a : **Typical spectral reflectance curve for vegetation, soil and water**



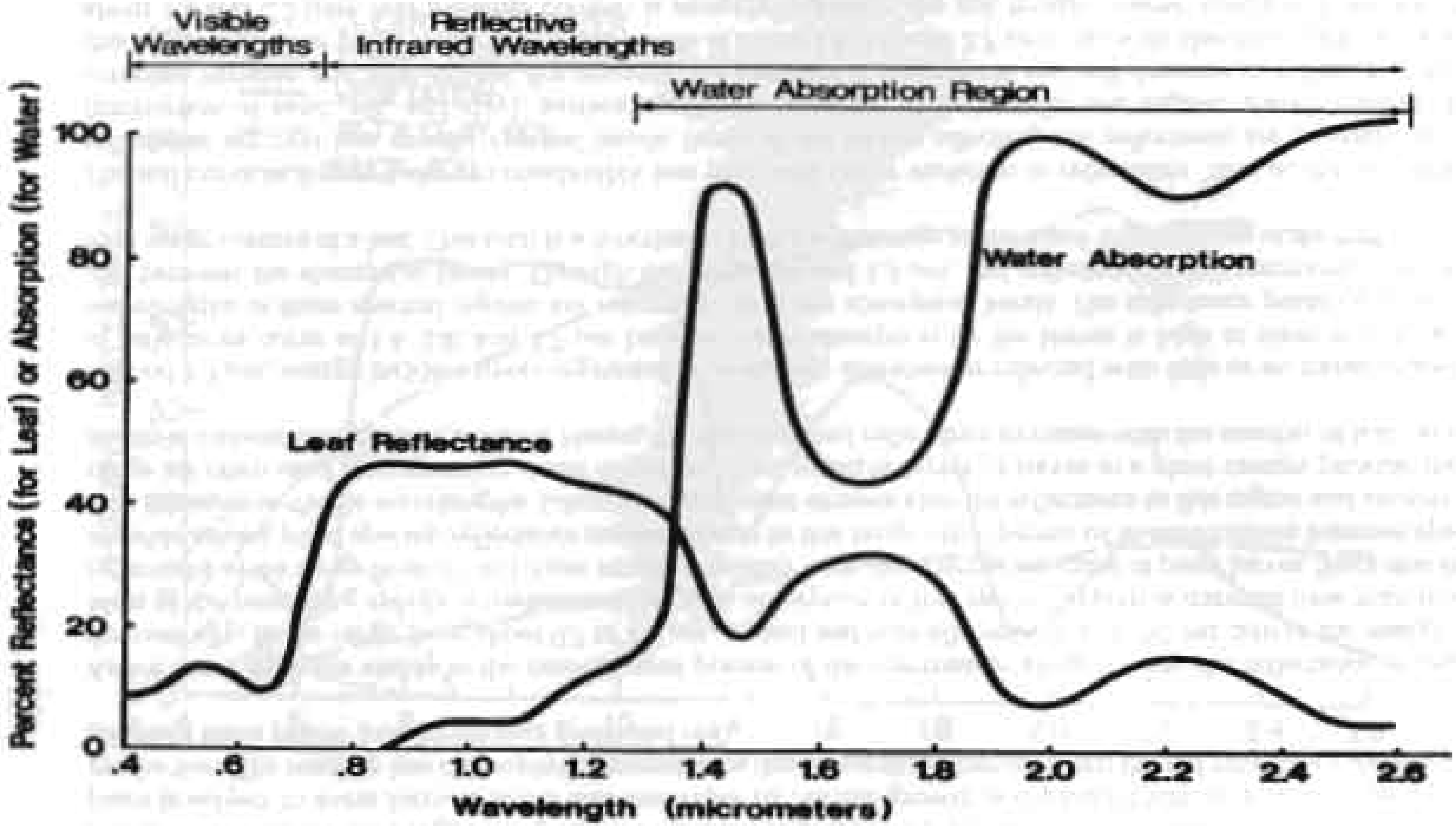
For example, spectral reflectance curves for vegetation almost always manifest the 'peak-and-valley' configuration in Figure 6. The alleys in the visible portion of the spectrum are dictated by the pigments in plant leaves. Chlorophyll, for example, strongly absorbs energy in the wavelength bands centred at about 0.45 and 0.67 µm. Hence, our eyes perceive healthy vegetation as green in colour because of the very high absorption of blue and red energy by plant leaves and the very high reflection of green energy. If a plant is subject to some form of stress that interrupts its normal growth and productivity, it may decrease or cease chlorophyll production. The result is less chlorophyll absorption in the blue and red bands. Often the red reflectance increases to the point that the plant turns yellow (combination of green and red).

As we move from the visible to the near-infrared portion of the spectrum at about 0.7 µm, the reflectance of vegetation increases dramatically. In the range from about 0.7 to 1.3 µm, a plant leaf typically reflects 40 to 50 per cent of the energy incident upon it. Most of the remaining energy is transmitted, because absorption in this spectral region is minimal (less than five per cent). Plant reflectance in the range from 0.7 to 1.3 µm results primarily from the internal structure of plant leaves. Since this structure is highly variable among plant species, reflectance measurements in this range often permit us to discriminate between species, even if they look the same in visible wavelengths. Likewise, many plant stresses alter the reflectance in this region and sensors operating in this range are often used for vegetation stress detection. Also, multiple layers of leaves in a plant canopy provide the opportunity for multiple transmittance and reflectance. Hence, the near-infrared reflectance increases with the number of leaf layers in a canopy.

Beyond 1.3 µm, energy incident upon vegetation is essentially absorbed or reflected with little or no transmittance of energy. Dips in reflectance occur at 1.4, 1.9, and 2.7 µm because water absorption by the leaves is high at these wavelengths. Accordingly, wavelengths in these spectral regions are referred to as water absorption bands. The reflectance peaks occur at about 1.6 and 2.2 µm, between the absorption bands. Through the range beyond 1.3 µm, leaf reflectance is approximately inversely related to the total water content of a leaf. This total is a function of both the moisture content and the thickness of the leaf.

The soil curve in Figure 6 shows considerably less peak-and-valley variation in reflectance. That is, the factors that influence soil reflectance act over less specific spectral bands. Some of the factors affecting soil reflectance are moisture content, soil texture (proportion of sand, silt, and clay), surface roughness, presence of iron oxide, and organic matter content. These factors are complex, variable, and inter-related. For example, the presence of moisture in soil will decrease its reflectance. As with vegetation, this effect is greatest in the water absorption bands at about 1.4, 1.9, and 2.7 µm (clay soils also have hydroxyl absorption bands at about 1.4 and 2.2 µm). Soil moisture content is strongly related to the soil texture; coarse, sandy soils are usually well drained, resulting in low moisture content and relatively high reflectance; poorly-drained, fine-textured soils will generally have lower reflectance. In the absence of water, however, the soil itself will exhibit the reverse tendency; coarse-textured soils will appear darker than fine-textured soils. Thus, the reflectance properties of a soil are consistent only within a particular range of conditions. Two other factors that reduce soil reflectance are surface roughness and organic matter content. The presence of iron oxide in a soil will also significantly decrease reflectance, at least in the visible wavelengths. In any case, it is essential that the analyst be familiar with the existing conditions.

Figure 6b : Relationship between water absorption and spectral reflectance in the middle - infrared wavelengths

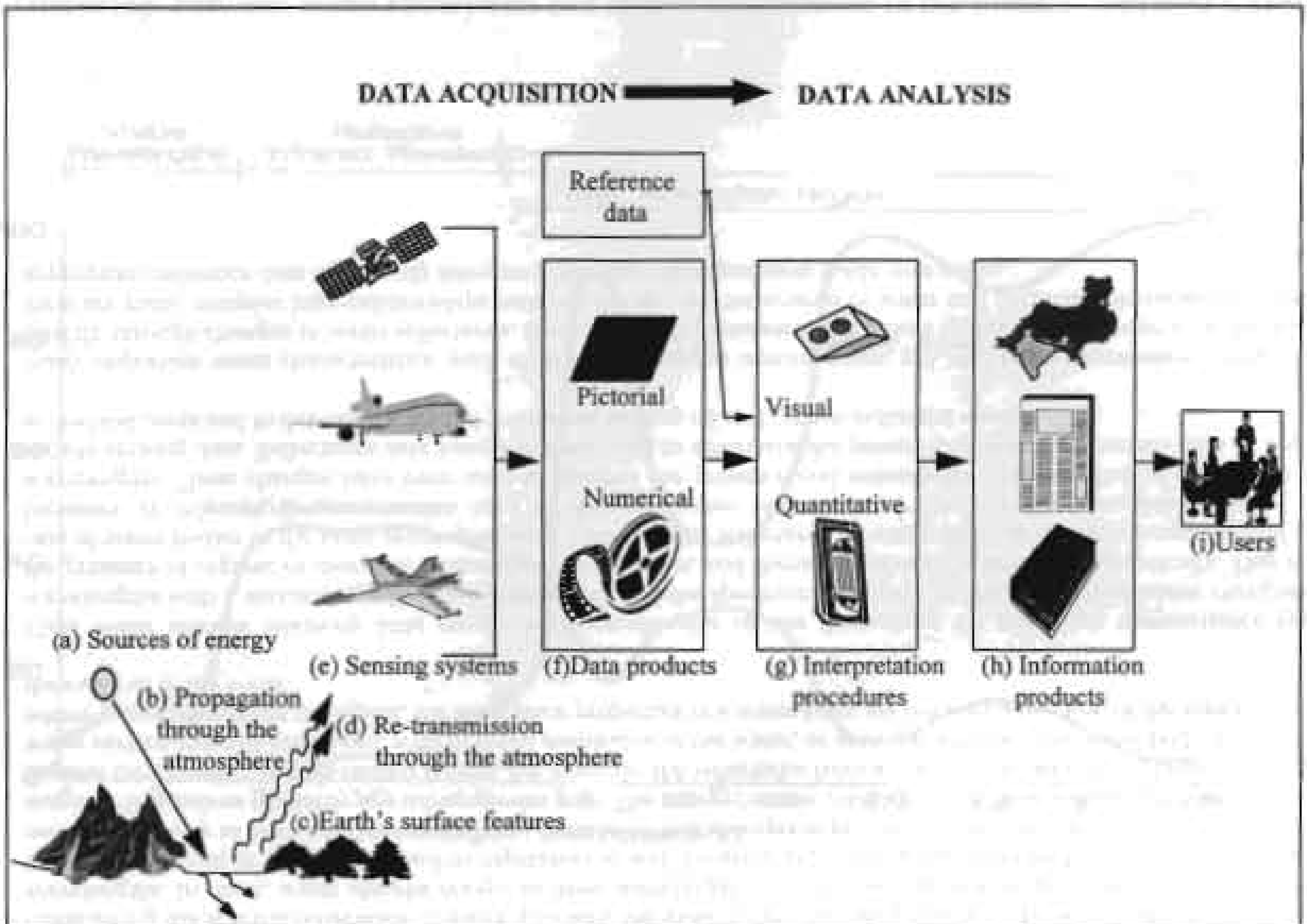


Considering the spectral reflectance of water, probably the most distinctive characteristic is the energy absorption at near-infrared wavelengths. In short, water absorbs energy in these wavelengths, whether we are talking about water features *per se* (such as lakes and streams) or water contained in vegetation or soil. Locating and delineating water bodies with remote-sensing data are carried out easily in near-infrared wavelengths because of this absorption property. However, various conditions of water bodies manifest themselves primarily in visible wavelengths. The energy/matter interactions at these wavelengths are very complex and depend on a number of inter-related factors. For example, the reflectance from a water body can stem from an interaction with the water surface (specula reflection), with material suspended in the water, or with the bottom of the water body. Even in deep water where bottom effects are negligible, the reflectance properties of a water body are not only a function of the water *per se* but also of the material in the water.

Clear water absorbs relatively little energy with wavelengths of less than about 0.6 μm. High transmittance typifies these wavelengths with a maximum in the blue-green portion of the spectrum. However, as the turbidity of water changes (because of the presence of organic or inorganic materials), transmittance, and therefore reflectance, changes dramatically. This is true in the case of water bodies in the same geographic area. Likewise, the reflectance of water depends on the concentration of chlorophyll. Increases in chlorophyll concentration tend to decrease water reflectance in blue wavelengths and increase it in green wavelengths. These changes have been used to monitor the presence and estimate the concentration of algae with the help of remote-sensing data. Reflectance data have also been used to determine the presence or absence of tannin dyes in bog vegetation in lowland areas and to detect a number of pollutants, such as oil and certain industrial wastes.

Many important water characteristics, such as dissolved oxygen concentration, pH, and salt concentration, cannot be observed directly through changes in water reflectance. However, such parameters sometimes correlate with observed reflectance. In short, there are many complex inter-relationships between the spectral reflectance of water and particular characteristics. One must use appropriate reference data to correctly interpret reflectance measurements made over water.

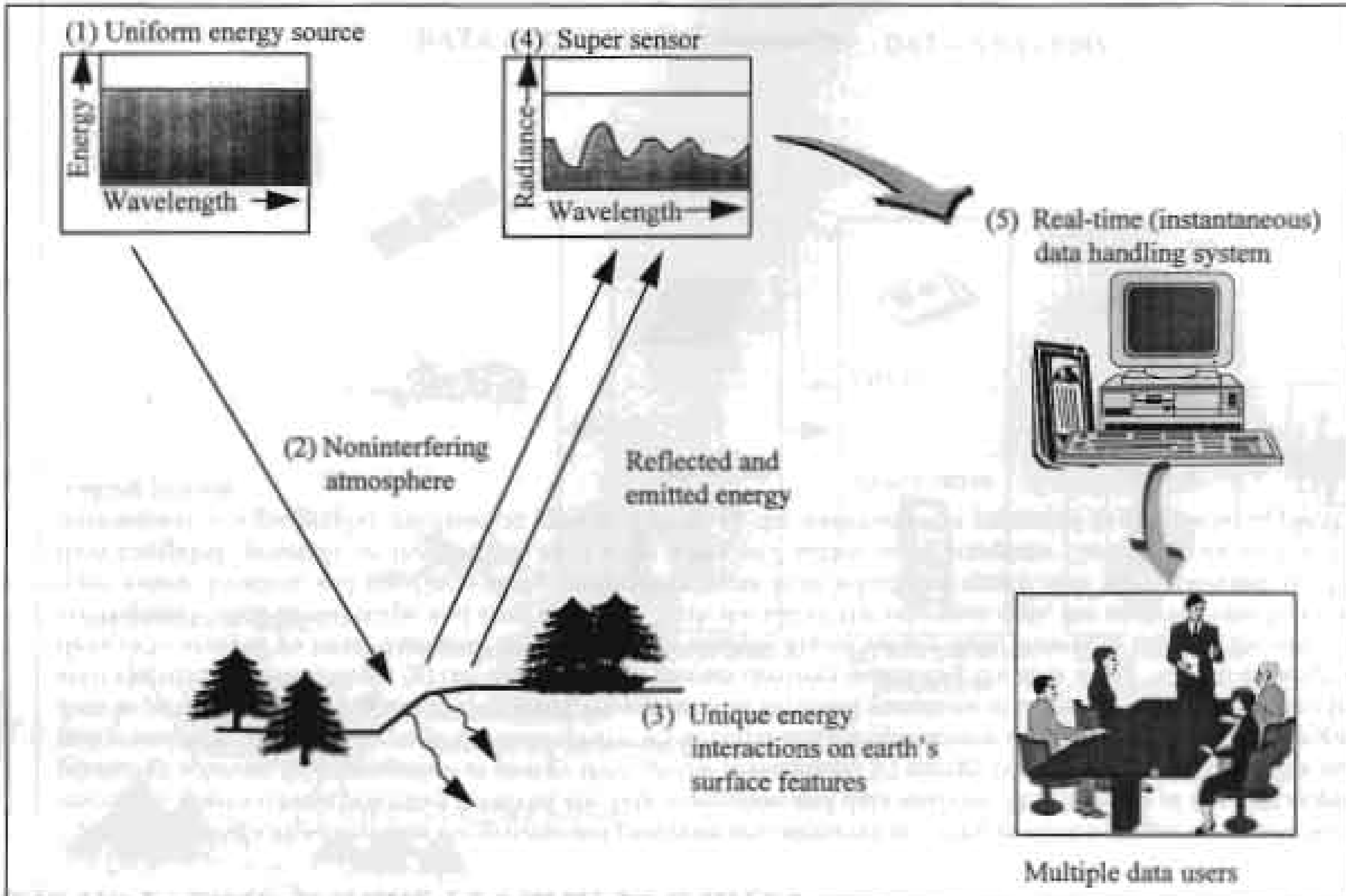
Figure 7: **Electro-magnetic remote sensing of the earth's resources**



Electro-Magnetic Remote Sensing Of Earth Resources

Figure 7 schematically illustrates the generalised processes and elements involved in electro-magnetic remote sensing of the earth's resources. The two basic processes involved are data acquisition and data analysis. The elements of the data acquisition process are (a) energy sources; (b) propagation of energy through the atmosphere; (c) energy interactions with the earth's surface features; (d) re-transmission of energy through the atmosphere; (e) airborne and/or spaceborne sensors; (f) resulting in the generation of sensor data in pictorial and/or digital form, in short, we use sensors to record variations in the way the earth's surface features reflect and emit electro-magnetic energy; (g)The data analysis process involves examining the data using various viewing and interpretation devices to analyse pictorial data and/or computers to analyse digital sensor data. Reference data on the resources being studied are required (such as soil maps and crop analysis). With the aid of the reference data, the analyst extracts information about the type, extent, location, and condition of the various resources from which the sensor data were collected; (h) This information is then compiled, generally in the form of hard copy maps and tables, or as computer files, to be merged with other 'layers' of information in a geographic information system. Finally, (i) the information is presented to users who apply it in their decision-making process.

Figure 8: **Components of an ideal remote-sensing system**



An Ideal Remote-Sensing System

Having introduced some basic concepts, we now have the necessary elements to conceptualise an ideal remote-sensing system. In doing so, we can then appreciate some of the problems encountered in the design and application of the various real remote-sensing systems examined in subsequent chapters.

The basic components of an ideal remote-sensing system are shown in Figure 8. These include the following components.

- *A uniform energy source. This source will provide energy over all wavelengths, at a constant, known, high level of output, irrespective of time and place.*
- *A non-interfering atmosphere. This will be an atmosphere that will not modify the energy from the source in any manner, whether that energy is on its way to the earth's surface or coming from it. Again, ideally, this will hold irrespective of wavelength, time, place, and sensing altitude involved.*
- *A series of unique energy/matter interactions at the earth's surface. These interactions will generate reflected and/or emitted signals that are not only selective in respect to wavelengths, but also are known, invariant, and unique to each and every earth surface feature type and subtype of interest.*
- *A super sensor. This will be a sensor, highly sensitive to all wavelengths, yielding spatially detailed data on the absolute brightness (or radiance) from a scene (a function of wavelength), throughout the spectrum. This super sensor will be simple and reliable, require virtually no power or space, and be accurate and economical to operate.*
- *A real-time data handling system. In this system, the instant the radiance versus wavelength response over a terrain element is generated, it will be processed into an interpretable format and recognised as being unique to the particular terrain element from which it comes. This processing will be performed nearly instantaneously (real time), providing timely information. Because of the consistent nature of the energy/matter interactions, there will be no need for reference data in the analytical procedure. The derived data will provide insight into the physical-chemical-biological state of each feature of interest.*
- *Multiple data users. These people will have comprehensive knowledge of both their respective disciplines and of remote-sensing data acquisition and analysis techniques. The same set of data will become various forms of information for different users, because of their vast knowledge about the particular earth resources being sensed. This information will be available to them faster, at less expense, and over larger areas than information collected in any other manner. With this information, the various users will make profound, considered decisions about how best to manage the earth resources under scrutiny and these management decisions will be implemented.*

Unfortunately, an ideal remote-sensing system, as described above, does not exist. Real remote-sensing systems fall far short of the ideal at virtually every point in the sequence outlined.

The Major Components Of Remote-sensing Technology

1. ENERGY SOURCE (PASSIVE SYSTEM: sun, irradiance from earth's materials; ACTIVE SYSTEM: irradiance from artificially-generated energy sources such as radar)
2. PLATFORMS (Vehicle to carry the sensor) (truck, aircraft, space shuttle, satellite, etc.)
3. SENSORS (Device to detect electro-magnetic radiation) (camera, scanner, etc)
4. DETECTORS (To convert electro-magnetic radiation into recorded signals) (film, silicon detectors, etc)
5. PROCESSING (Handling signal data) (photographic, digital, etc)
6. INSTITUTIONALISATION (Organisation for execution at all stages of remote-sensing technology: international and national organisations, centres, universities, etc

Platforms

The vehicles or carriers for remote sensors are called the platforms. Typical examples of platforms are satellites and aircraft, but they can also include radio-controlled aeroplanes, balloons, kits for low altitude remote sensing, as well as ladder trucks or 'cherry pickers' for ground investigations. The key factor for the selection of a platform is the altitude that determines the ground resolution and which is also dependent on the instantaneous field of view (IFOV) of the sensor on board the platform.

Remote-Sensing Platforms

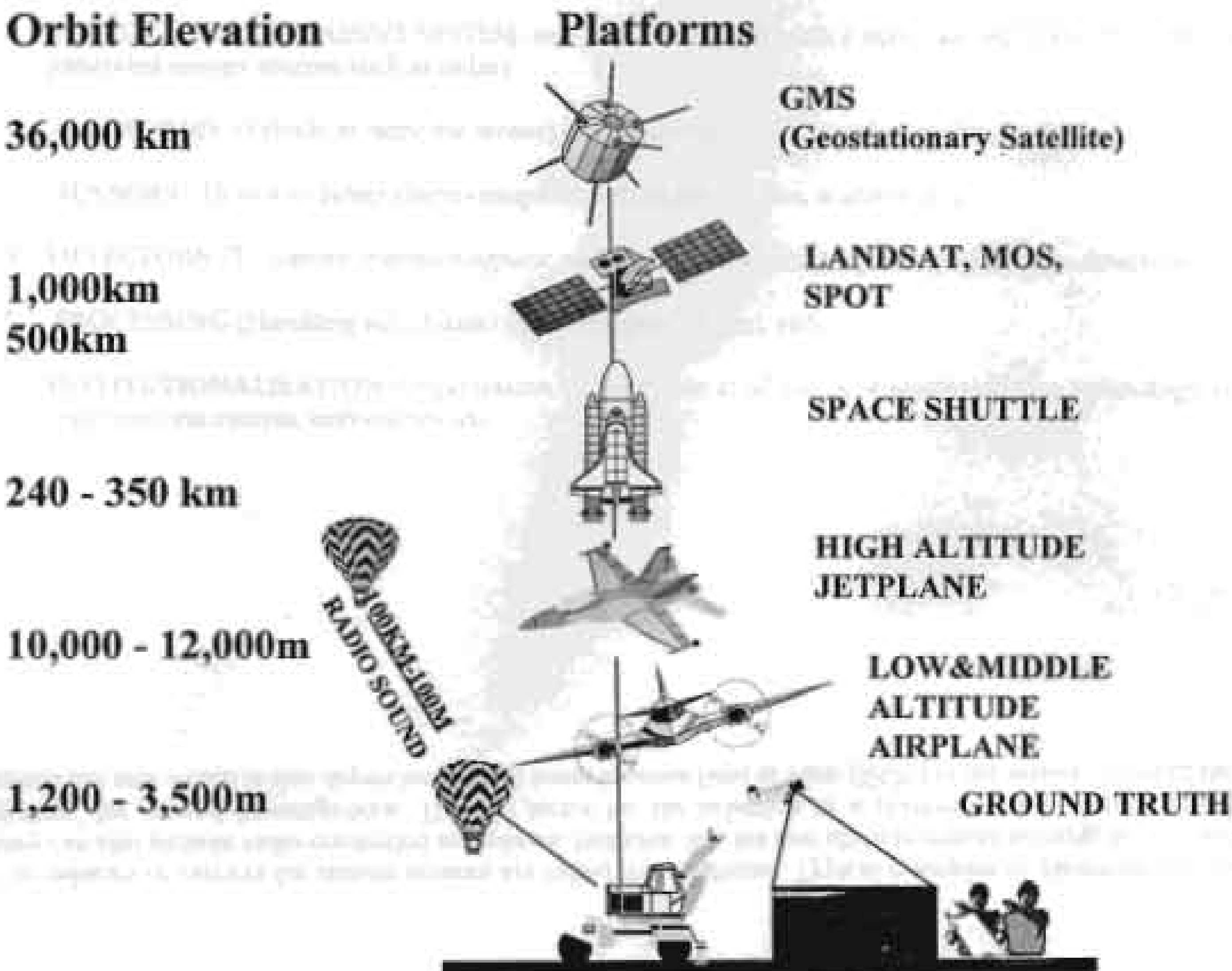


Table 3 : Platform Types And Observation Objects

Platform	Altitude	Observation	Remarks
geostationary satellite	36,000km	fixed point observation	GMS
circular orbit satellite (earth observation	500km - 1,000km	regular observation	LANDSAT, SPOT, MOS, etc
space shuttle	240km - 350km	irregular observation space experiment	
radio - sound	100m - 100km	various investigations (meteorological, etc)	
high altitude jet-plane	10km -12km	reconnaissance wide area investigations	
low or middle altitude plane	500m - 8,000m	various aero investigation surveys	
helicopter	100m- 2,000m	various aero investigation surveys	
radio-controlled plane	below 500m	various aero investigation surveys	aeroplane, helicopter
hang-plane	50 - 500m	various aero investigation surveys	hang-glider,paraglider
hang-balloon	800m -	various investigations	
cable	10 - 40m	archaeological investigations	
crane car	5 - 50m	close range surveys	
ground measurement car	0 - 30m	ground truth	cherry picker

Sensors

As sensor or 'remote sensor' is a device to detect the electro-magnetic radiation reflected or emitted from an object. Cameras or scanners are examples of remote sensing-sensors.

Table 4 : Classification of Sensors

Passive

- Non-scanning
  - Non-imaging
  - Microwave Radiometer
  - Magnetic Sensor
  - Gravimeter
  - Fourier Spectrometer
  - Other
- Imaging
  - Camera
    - Monochrome
    - Natural colour
    - Infrared
    - Other

Scanning

- Imaging
  - Image Plane Scanning
    - TV Camera
    - Solid Scanner
  - Object Plane Scanning
    - Optical Mechanical Scanner
    - Microwave Radiometer

Active

- Non-scanning
  - Non-imaging
    - Microwave Radiometer
    - Microwave Altimeter
    - Laser Water Depth meter
    - Laser Distance meter
- Scanning
  - Imaging
    - Object Plane Scanning
      - Real Aperture Radar
      - Synthetic Aperture Radar
    - Image Plane Scanning
      - Passive Phased Array Radar

Classification of Sensors

PASSIVE SENSORS detect the reflected or emitted electro-magnetic radiation from natural sources, while **ACTIVE SENSORS** detect reflected responses from objects that are irradiated from artificially-generated energy sources such as radar. Each is divided further into **non-scanning** and **scanning** systems.

A sensor classified as a combination of passive, non-scanning and **non-imaging methods** is a type of profile recorder, one example is a microwave radiometer. An example of a sensor classified as a passive, **non-scanning imaging method** is a camera, e.g., an aerial survey camera or a space camera, for example Large Format Cameras (LFCs) on board Space Shuttles.

Sensors classified as a combination of passive, scanning, and imaging are classified further into **image plane scanning sensors**, such as TV cameras and solid state scanners, and **object plane scanning sensors** such as multi-spectral scanners (optical-mechanical scanners) and scanning microwave radiometers.

An example of an active, non-scanning and non-imaging sensor is a profile recorder such as a laser spectrometer and a laser altimeter. An active, scanning and imaging sensor is a radar, for example synthetic aperture radar (SAR), which can produce high resolution, imagery, day or night, even under cloud cover.

The most popular sensors used in remote sensing are the camera; the solid state scanner, such as the CCD (charge coupled device) images; the multi-spectral scanner; and, in the future, the passive synthetic aperture radar. Recently laser sensors have come into more frequent use for monitoring air pollution by laser spectrometer and for measurement of distance by laser altimeter. Sensors that use lenses in the visible and reflective infrared region are called optical sensors.

Table 5 : Wavelength Band of Principal Sensor

Wavelength (µm)	**U V**	**VISIBLE**		**INFRARED Near S.W. Interm. Thrm. Far**								**RADIO**
SENSOR	0.4	0.5	0.6	0.7	0.9	1.5	5.5	8.0	14	1000	10000	100000
(CAMERAS:) monochrome film	—	—	—	—								
Colour film	—	—	—	—								
IR film				—	—							
Colour IR film		—	—	—	—							
SOLID SCANNER (SPOT HRV)		—	—	—	—							
(Thermal Video)							—	—	—			
TV CAMERA	—	—	—	—								
OPTICAL MECHANICAL SCANNER												
(Airborne MSS)	—	—	—	—				—	—			
(Landsat MSS)		—	—	—								
(Landsat TM)	—	—	—	—	—	—		—	—			
RADAR										—	—	—
MICROWAVE RADIOMETER										—	—	—

Characters of Optical Sensors Optical sensors are characterised by spectral, radiometric, and geometric specifications.

Table 6 : Elements of optical sensor characteristics

Spectral characteristics

- observation range of EMW
- change of both ends of a band
- sensitivity on out of a band
- polarisation sensitivity
- sensitivity difference between different bands
- ...

Radiometric characteristics

- detecting accuracy
- signal to noise ratio
- dynamic range
- quantisation level
- sensitivity difference between pixel
- linearity of sensitivity
- noise equivalent power
- ...

Geometric characteristics

- field of view
- instantaneous field of view
- registration between different spectral bands
- alignments
- modulation transfer function
- optical distortion
- ...

Definition of Optical Sensor's Characteristics

Items	Definition
band range of EMW	observation width of EMW (Electro-magnetic waves) on a band
centre wavelength	centre wavelength on band
band responsibility at both ends of a band	characteristics' curve at both ends of a band
band sensitivity	sensitivity on a band
without band sensitivity	sensitivity on spectral ranges outside of the band
sensitivity difference between different bands	ratio of sensitivity between different bands
S/N ratio	signal to noise ratio
dynamic range	range of sensor's sensitivity in terms of the difference between maximum and minimum radiance ratio
sensitivity difference between pixels	ratio of maximum output level to minimum output level pixels
linearity of sensor's input-output characteristics	input level to output level in higher input power level
noise equivalent power	input signal power giving output equivalent with noise power
field of view	area covered by a remote sensor, picture (angular field of camera, scanning width by scanner)
instantaneous field of view (IFOV)	field of angle detected by one detector
registration between different spectral bands	geometric distortion between one standard band and other bands
MTF	modulation transfer function of a sensor, determining the sensor's IFOV
optical distortion	image distortion due to optical components of a sensor, e.g., lens aberration
angle of stereoscopic observation	difference of viewing angle of stereoscopic sensors
imaging frequency	time taken for scanning one line

Resolution

(1) Spectral Resolution

(2) Radiometric Resolution

(3) Spatial Resolution

(4) Temporal Resolution

Resolution

In general, resolution is defined as the ability of an entire remote-sensing system, including lens, antennae, display, exposure, processing, and other factors, to render a sharply-defined image. Resolution of a remote-sensing system is of different types.

(1) Spectral Resolution

(2) Radiometric Resolution

(3) Spatial Resolution

(4) Temporal Resolution

The **spectral resolution** of a remote sensing instrument (sensor) is determined by the band-widths of the EMR of the channels used. High spectral resolution, thus, is achieved by narrow band widths which, collectively, are likely to provide a more accurate spectral signature for discrete objects than broad band width. However, narrow-band instruments tend to acquire data with a low signal-to-noise ratio (the ratio of effective input signal to the noise level), lowering the system's radiometric resolution. This problem may be alleviated if relatively long look (or dwell) times are used during imaging. In contrast, broad-band sensors usually have good spatial and radiometric resolution. In the broader usages of spectral resolution, there are also tradeoffs between application and spectral and radiometric resolution. In remote sensing, the data from a multiple number of channels or bands, which divide the electro-magnetic radiation range from ultra violet to radio waves are called multi-channel data, multi-band data, or multi-spectral data.

Radiometric resolution is determined by the number of discrete levels into which signals may be divided. Considering the effects of varying illumination, the radiometric dynamic range of a sensor is determined by the maximum radiance value that the sensor system can experience for a given band. For example, the initial analogue voltage signal of the Landsat (1,2,3) MSS detectors is converted to digital count output ranges from 0 to 63 for a total of 64 quantizing levels. However, the maximum number of quantizing levels possible from a sensor system depends on the signal-to-noise ratio and the confidence level that can be assigned when discriminating between levels. Information contained in digital image data are expressed by bit (binary digit) per pixel, per channel. A bit is a binary number, that is 0 or 1. Let the quantization level be n, then the information in terms of bits is given by $\log_2 n$ (bit). In remote sensing, the quantization level is normally 6, 8 or 10 bits. For computer processing, the byte unit (1 byte =8bits; integer value 0-255; 256 gray levels) is much more convenient. Therefore, remote-sensing data will be treated as one or two byte data.

The total data volume of multi-channel data per scene is computed as:

data volume (byte)=(line number)*(pixel number)*(channel number)*(bits)/8.

Table 7 : **Quantization level of remote-sensing data**

Sensor	Satellite	Level (bit)	Descriptions
TM	LANDSAT	6	8 bits data after radiometric correction
MSS	LANDSAT	8	
HRV (XS)	SPOT	8	
HRV (PA)	SPOT	6	
AVHRR	NOAA	10	both 10 and 16 bits' data are available at distribution
SAR	JERS-1	3	real 3 bits, imaginary 3 bits

Spatial resolution, in terms of the geometric properties of the imaging system, is usually described as the instantaneous field of view (IFOV). The IFOV is defined as the angle which corresponds to the sampling unit on the ground. The IFOV is a function of satellite orbital altitude, detector size, and the focal length of the optical system. Thus, the IFOV, when expressed in degrees or radians, is the smallest plane angle over which an instrument (e.g., a scanner) is sensitive to radiation; when expressed in linear or area units, such as metres or hectares, it is an altitude-dependent measure of the ground resolution of the scanner, in which case it is also called an 'instantaneous viewing area'. The field of view (FOV) is defined as the maximum angle of view in which a sensor can effectively detect electro-magnetic energy. Ground resolution is the minimum detectable area or distance on the ground. In some cases, the projected area on the ground corresponding to a pixel or IFOV is also called ground resolution. Swath width (also called the total field of view [TFOV]) is the width on the ground corresponding to the FOV.

Temporal resolution is related to the repetitive coverage of the ground coverage by the remote-sensing system. The temporal resolution of Landsat 4/5 is sixteen days. There are very few objects and/or phenomena in nature that do not change in respect to one another throughout the course of time. For many of the physical and cultural features on the landscape, there are optimal time periods during which these features may best be observed. These optimal periods might be seasonal, or could last only for a few days or weeks. In the case of some applications, the time interval at which remotely-sensed data are acquired becomes an important factor. For example, to monitor crop growth, images should be obtained at a predetermined time interval within a year's period. However, to monitor urban growth patterns, imagery acquired at time intervals of a year or more may be appropriate. Thus, in remote sensing, a substantial number of dynamic events, such as crop growth, rangeland development, hydrologic processes, earth damage, urban change, and marine processes; may be used as key discriminants.

Remote-Sensing Satellites

A satellite with remote sensors to observe the earth is called a remote-sensing satellite, or earth observation satellite. Meteorological satellites are sometimes discriminated from other remote-sensing satellites.

Remote-sensing satellites are characterised by their altitude, orbit, and sensor. The Television and Infrared Observation Satellite (TIROS) series (1960 - 1965), the first generation of National Oceanic and Atmospheric Administration (**NOAA**) satellites was the first operational remote-sensing satellite system. The main purpose of the **geo-synchronous meteorological satellite (GMS),** with an altitude of 36,000 km, is meteorological observations, while **LANDSAT,** with an altitude of about 700 km, is a polar orbit and is used mainly for land area observation. The **NOAA** satellite series, the third generation meteorological satellites operated by the **NOAA** , USA, with **Advanced Very High Resolution Radiometer (AVHRR)** sensors, with an altitude of 850 km in a polar orbit, is mainly designed for meteorological observation but is also successfully used for vegetation monitoring. There are several remote-sensing satellite series in operation at present **(LANDSAT, NOAA, SPOT, MOS, JERS, ESR, RADARSAT, IRS, etc).** In the future some remote-sensing satellites will have large payloads with many kinds of multipurpose sensors, such as the polar orbit platform (POP) project under the international cooperation of the US, EEC, Japan, and Canada. Also, there will be more specialised missions using small satellites.

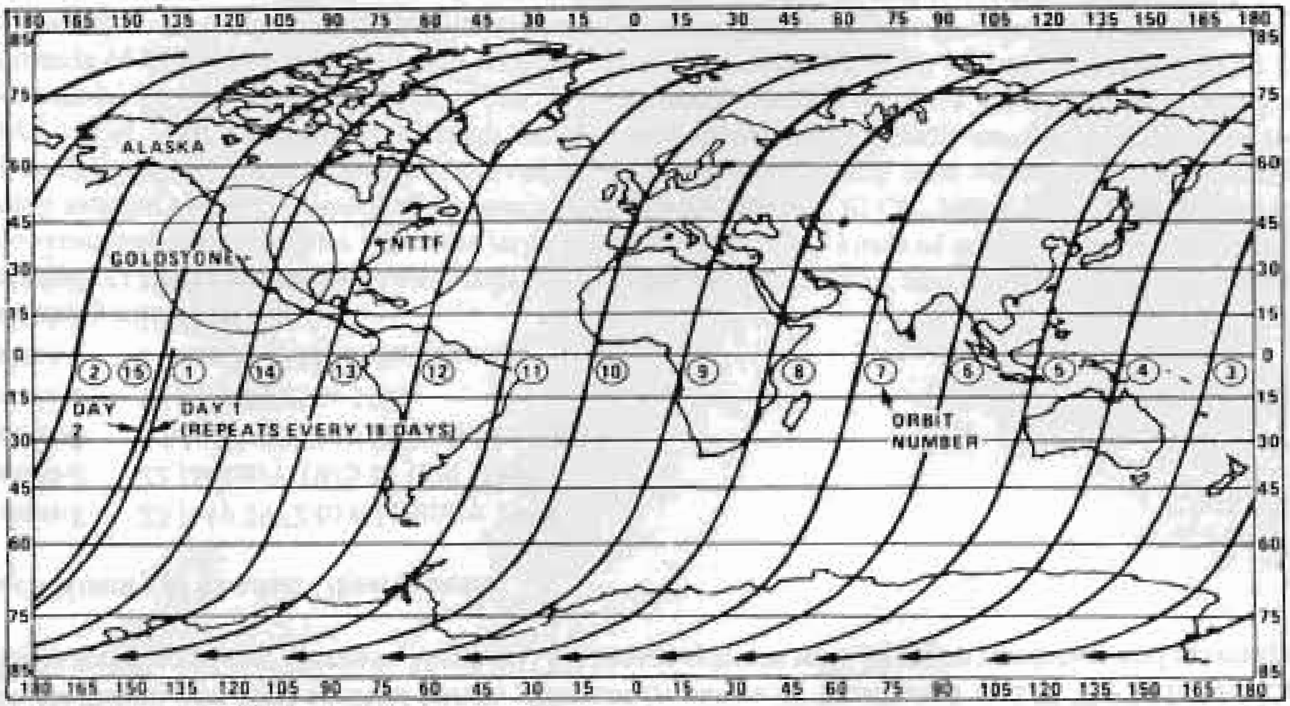
LANDSAT

Landsat-1 was launched by the USA in 1972 and was the first earth observation satellite in the world that introduced the remarkable advance of remote sensing. To date, five Landsats (Landsats 1 - 5) have been launched, with only Landsat 5 still in operation. Landsats 1 to 3 are sometimes called first generation Landsats. They had Multispectral Scanner (MSS) systems with 80 metre resolution and four spectral bands, different in nature to Landsats 4 and 5. The latter are called the second generation Landsats series and have Thematic Mapper (TM) sensor systems with 30 metre resolution and seven spectral bands.

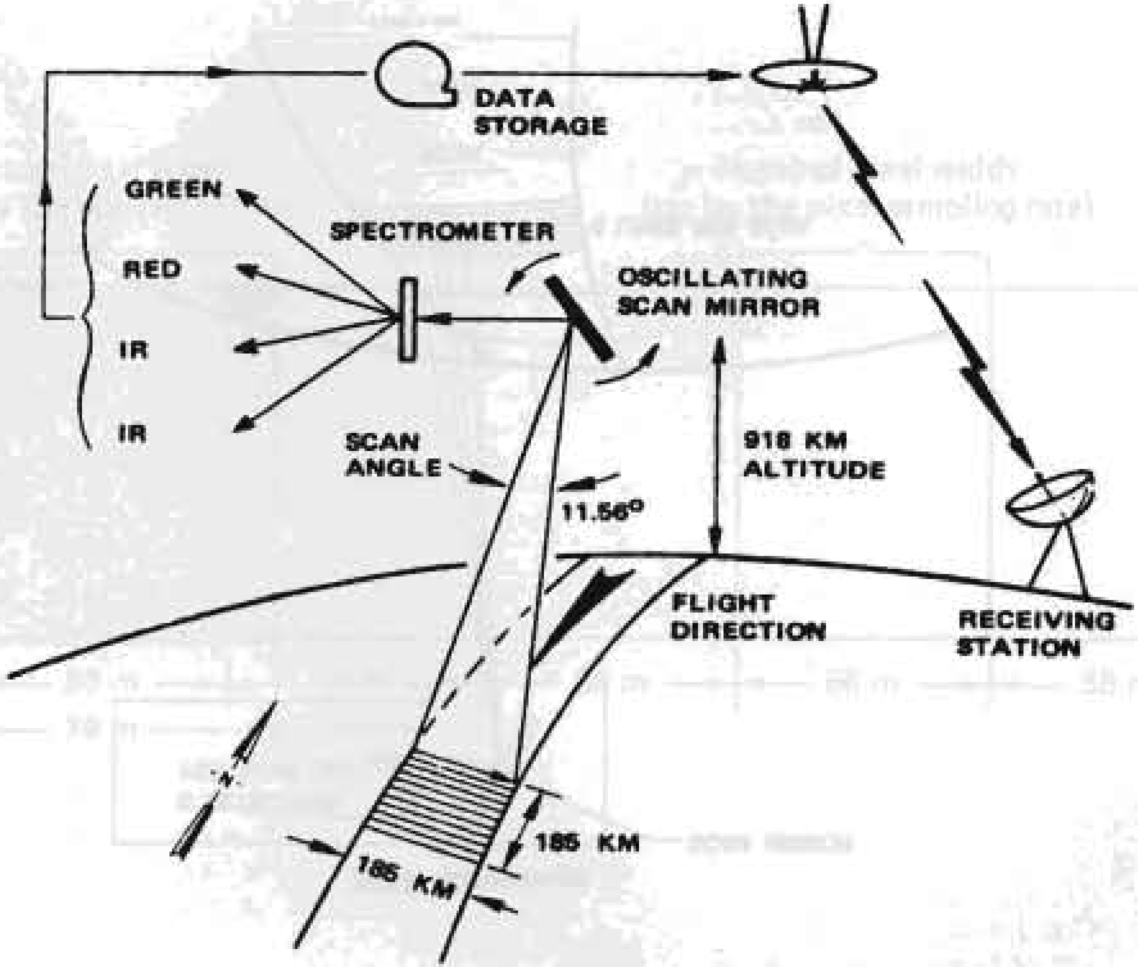
Launch History of Landsat Observatories

Landsat-1	23 July 1972 to 6 January 1978
Landsat-2	22 January 1975 to July 1983
Landsat-3	5 March 1978 to September 1983
Landsat-4	16 July 1982 to 1991
Landsat-5	1 March 1984 to the present
Landsat-6	1993 (failure)
Landsat-7	1998 (scheduled)

Typical Landsat 1, 2, 3 ground trace for one day
(only the active southbound passes shown)

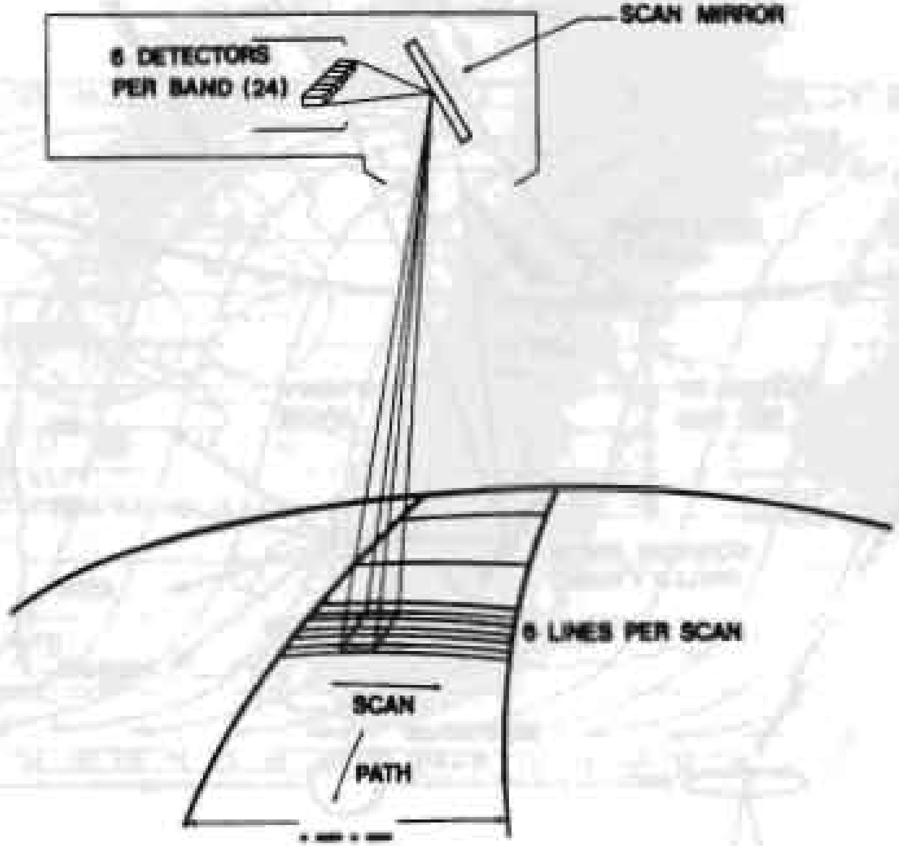


Landsat MSS Operating Configuration

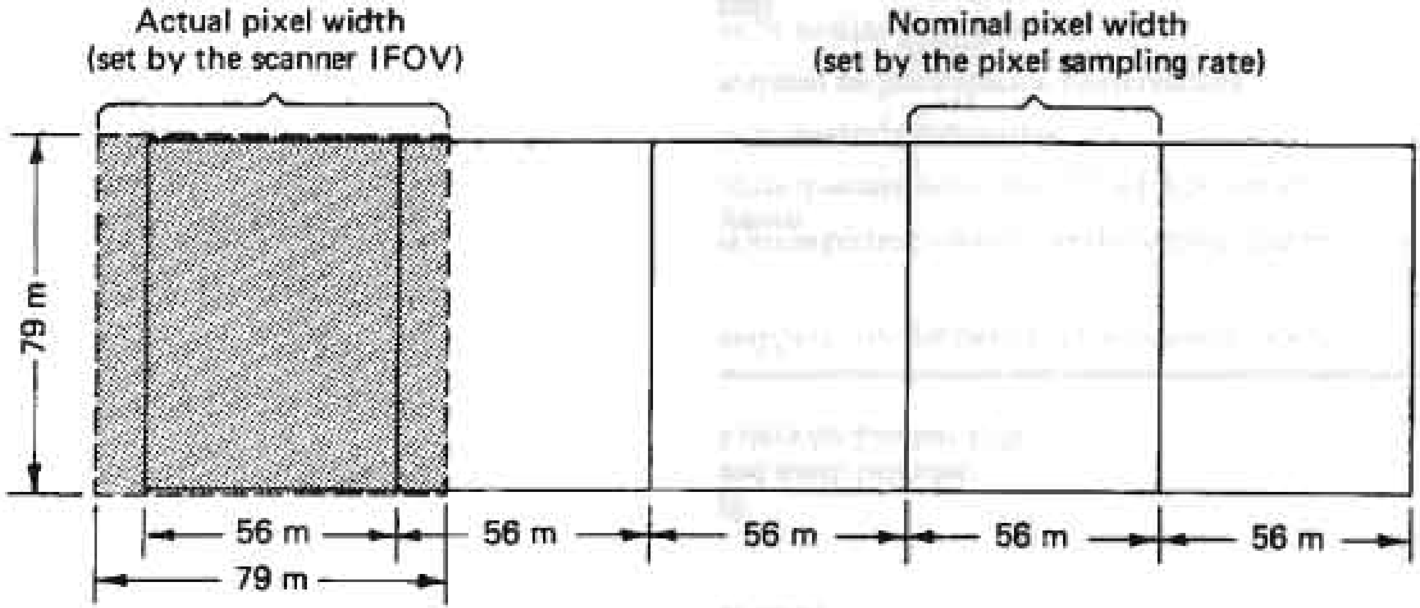


Ground Trace for Multispectral Scanner (MSS)

MSS Coverage



Ground Resolution Cell Size Versus MSS Pixel Size



Landsats 1, 2, and 3: (some of the silent features of Landsat 1, 2, and 3)

3 metres' tall
1.5 metres' in diameter
4-metre solar panel extensions
ground track speed of 6.46 km per sec
about a 9 degree angle at the equatorial path
about 2,760 km apart at the equator of the successive orbits
185 km swath image by sensor on board (total field of view)
about a 900 km nominal altitude (880 - 940 km)
14 orbits per day (14½ days for Landsat 4/5)
14 per cent overlap at the equator (minimum overlap)
85 per cent overlap (maximum) at 81 degrees north and south latitudes
18 days' repetitive coverage (temporal resolution)(16 days for Landsat 4/5)
103-minute orbital period
sun-synchronous orbit (same local sun time)
9:42 AM local sun time on each pass at the equator
25 secs per scene is the rate of data generation
7,581,600 pixels per channel per scene
33 milliseconds per mirror oscillation of the sensor system
about 100,000 samples per sec output of detectors
80-metre resolution (IFOV) (57 m * 79 m)
sensor system

MSS (Multispectral Scanner)
spectral resolutions (wavelength regions)

Band-4	(0.5 to 0.6 µm)
Band-5	(0.6 to 0.7 µm)
Band-6	(0.7 to 0.8 µm)
Band-7	(0.8 to 1.1 µm)
Band-?	(10.4 to 12.6 µm) (failure)

RBV (Return Beam Videocon) (partially ? failure)

Table 8 : **Thematic Mapper (TM) Spectral Bands on Board Landsats 4 And 5's Sensor System and Their Potentials Application.**

Band Range (µm)	Potential applications
1 0.45 to 0.52	coastal water mapping; soil/vegetation differentiation; deciduous/coniferous differentiation (sensitive to chlorophyll concentration), etc
2 0.52 to 0.62	green reflectance by healthy vegetation, etc
3 0.63 to 0.69	chlorophyll absorption for plant species differentiation
4 0.78 to 0.90	biomass surveys; water body delineation
5 1.55 to 1.75	vegetation moisture measurement; snow/cloud differentiation
6 10.4 to 12.5	plant heat stress management; other thermal mapping; soil moisture discrimination
7 2.08 to 2.35	hydrothermal mapping; discrimination of mineral and rock types

Table 9 : **Summary of some studied satellites.**

Satellites	Landsat 4/5		NOAA 9/10	SPOT 1 - ...		MOS 1 - ...		
Orbit type	SUN SYNCHRONOUS AND NEAR POLAR							
Orbit altitude (km)	706		870	832		980		
Revisit cycle (in days)	16		1 image/day	3 (side look) 20 (nadir)		17		
Sensors	MSS	TM	AVHRR	HRV 1 & 2		M E S S R	V I T R	M S R
Sensors (types)	Scanners		Scanners	Push-brooms		Scanners		
IFOV (ground resolution)	80 m	30 m	1 km 4 km	10m (PA)	20 m (XS)	50m	900m, 2.7km	30km, 20 km
Number of Spectral Bands	4	7	5	1	3	4	4	2
Portion of Electro-magnetic Spectrum	VIS + IR	VIS + IR + T.IR	VIS + IR + T.IR	Pan-chro-matic	VIS + IR	VIS + IR	VIS + IR + T.IR	Microw-ave
Swath width (km)	185		2700	60		100	1500	300

Table 10 : **Spectral bands and wavelengths in μm**

Spectrum	LANDSAT MSS	LANDSAT TM	SPOT XS	NOAA AVHRR	MOS MESSR
Blue		0.45 - 0.52			
Green	0.50 - 0.60	0.53 - 0.61	0.50 - 0.59		0.51 - 0.59
Red	0.60 - 0.70	0.62 - 0.69	0.62 - 0.68	0.58 - 0.68	0.61 - 0.69
NIR	0.70 - 0.80	0.78 - 0.90	0.78 - 0.88	0.73 - 1.10	0.72 - 0.82
NIR	0.80 - 1.10				0.80 - 1.10
IIR(MIR)		1.57 - 1.78			
IIR(MIR)		2.10 - 2.35		3.55 - 3.93	
ThIR		10.45-11.66		10.3 - 11.2	
FIR				11.5 - 12.5	

NOAA - Satellites

The third generation satellite series of the National Oceanic and Atmospheric Administration (NOAA), USA

N0AA-9 (launched 1984), **NOAA-10** (launched 1986), NOAA - 14 (launched 1994)

SENSOR: **AVHRR, TOVS-SSU, TOVS-MSU, SBUV/2, ERB**

AVHRR 'Advanced Very High Resolution Radiometer'
Resolution at nadir = 1 km
Resolution at edge = 1.4 km
Swath width = 2,700 km
Scanning angle = 99 degrees
inclination = 1,12 degrees
Sun-synchronous orbit / altitude = 870 km
Two night pass and two day pass images (a total of four images per place in 24 hours)

NOAA/AVHRR Spectral Bands and Their Potential Application

Channel Number	Wavelength (µM)	Uses
Channel 1	0.58 - 0.68	cloud delineation, weather, snow, and ice mapping and monitoring, etc
Channel 2	0.73 - 1.1	surface water delineation, vegetation and agricultural assessment, range surveys, etc
Channel 3	3.53- 3.93	land/water distinction, sea surface temperature, hot spot detection (forest fires and volcanic activity),etc
Channel 4	10.3 - 11.3	day/night cloud mapping, sea and land surface temperature, soil moisture, volcanic eruption, etc
Channel 5	11.5 12.5	sea surface temperature measurement, soil moisture, weather, etc

MOS - Satellites

('Marine Observation Satellite')

(Japanese)

MOS - 1a launched on 19 February 1987; **MOS -1b** on February 7, 1990

Satellite Orbit
sun-synchronous orbit
altitude = 909 km
inclination angle = 99.1 degree
revisit cycle = 17 days

Sensors: MESSR (two). VTIR (one), MSR (one)

MESSR Multispectral Electronic Self Scanning Radiometer)
Four spectral bands similar to those of LANDSAT MSS

Band-1	0.51 - 0.59 µm
Band-2	0.61 - 0.69 µm
Band-3	0.72 - 0.80 µm
Band-4	0.80 - 12.5 µm

IFOV = **50m** (resolution)
TFOV = 100 Km (swath width)
General ground information (forest, soil, sea surface color, vegetation, land, etc)

VTIR Visible Thermal Infrared Radiometer)
Four spectral bands compatible with NOAA AVHHR
0.5 - 0.69 µm
6.0 - 9.00 µm
10.5 - 11.50 µm
11.5 - 12.50 µm

MOS.....

IFOV

visible = 900 m
Infrared = 2.7 km

TFOV = 1500 km (swath width)
Mainly designed for sea surface temperature measurement

MSR Microwave Scanning Radiometer)
Frequency (K band) (S. H.Frequency)

23.8 Ghz

IFOV = 31 km
Water vapour content, rainfall area measurement, and snowfall measurement

31.4 Ghz

IFOV = 23 km
Ice measurement, measurement of water content in the clouds, and snowfall measurement

SPOT

(System Probatoire d'Observation de la Terre)

(France)

SPOT-1 1986
SPOT-2 1990
SPOT-3 1993
SPOT-4 (1997)

Orbit

Altitude = 830 km
Inclination = 98.7 degree
Sun-synchronous and semi-recurrent orbit
Time of passage of the equator = 10:30 a.m.
Recurrent (revisit capability) = 26 days nominally but 4 to 5 days if observed with oblique pointing

Ground coverage (swath width) (TFOV)

Nadir coverage = 60 km x 60 km
Oblique coverage of 81 sq. km. at a maximum look angle of 27 degrees

GRS

SPOT Grid Reference System
k = column, j = row

SPOT...

Stereo capability

Strip selection mirror of up to +27 to -27 degrees in across-track direction

Sensors

Two HRV (High Resolution Visible Imaging System)
HRV1 and HRV2

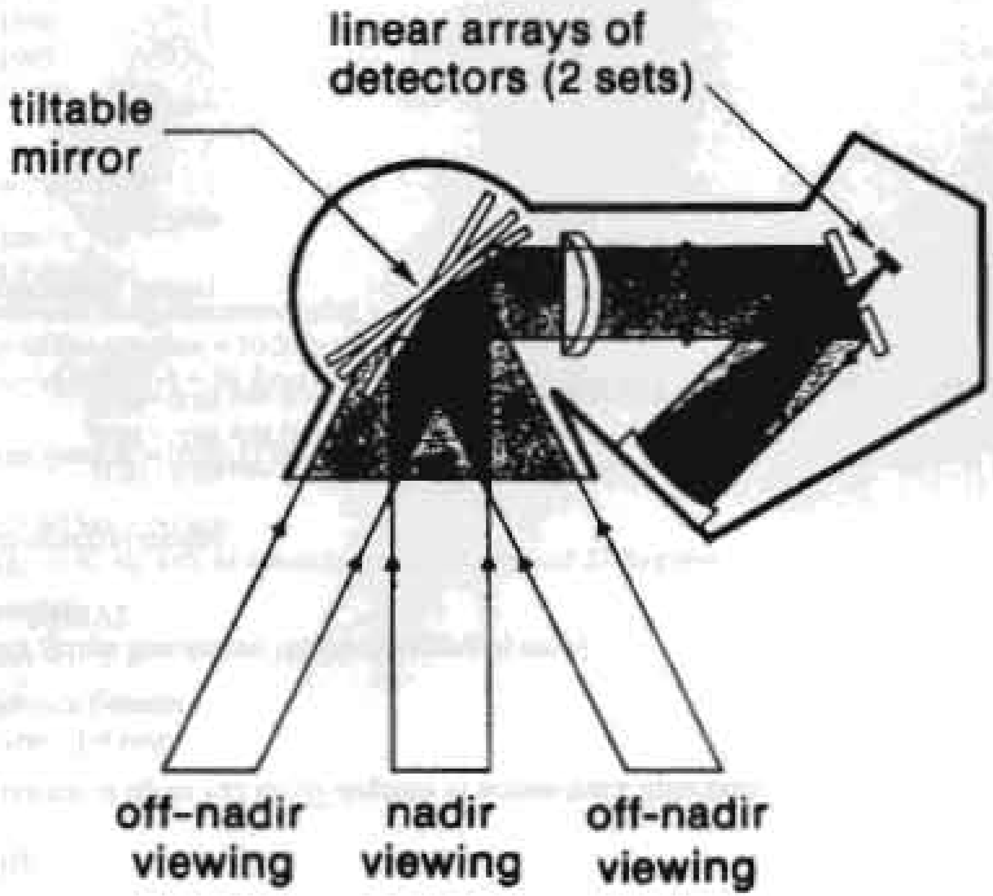
XS mode (Multi-spectral mode)

XS1	0.50 - 0.59 μm (green wavelength region)
XS2	0.61 - 0.68 μm (red wavelength region)
XS3	0.79 - 0.89 μm (near infrared wavelength region)
IFOV	20 m

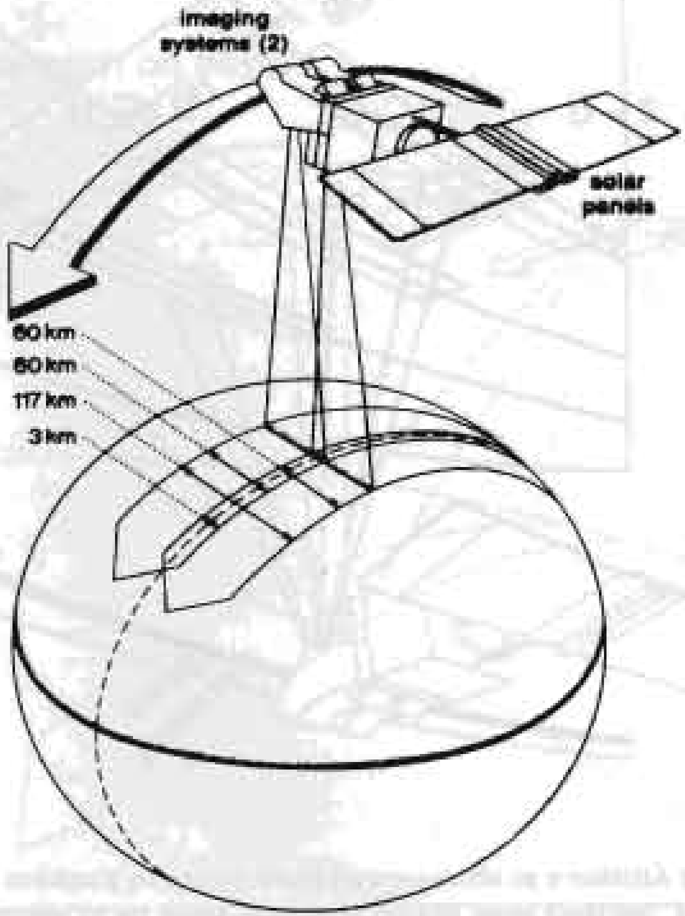
PA mode (Panchromatic mode)

PA	0.5-0.7μm
IFOV =	10m

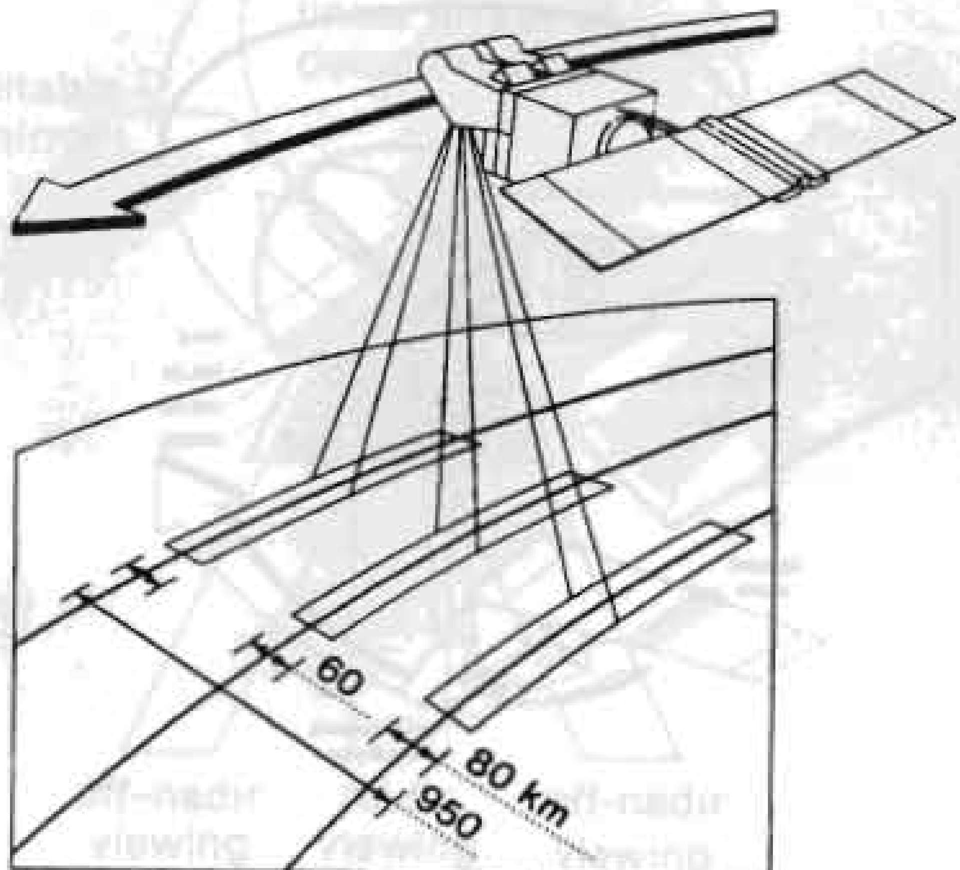
Oblique viewing capability of SPOT HRV instruments. SPOT's two HRV (High Resolution Visible) instruments on board are each fitted with steerable mirrors (strip selectable mirrors) which enable the instruments to image areas up to 27° east or west of the vertical, enabling them to give stereoscopic pairs of images



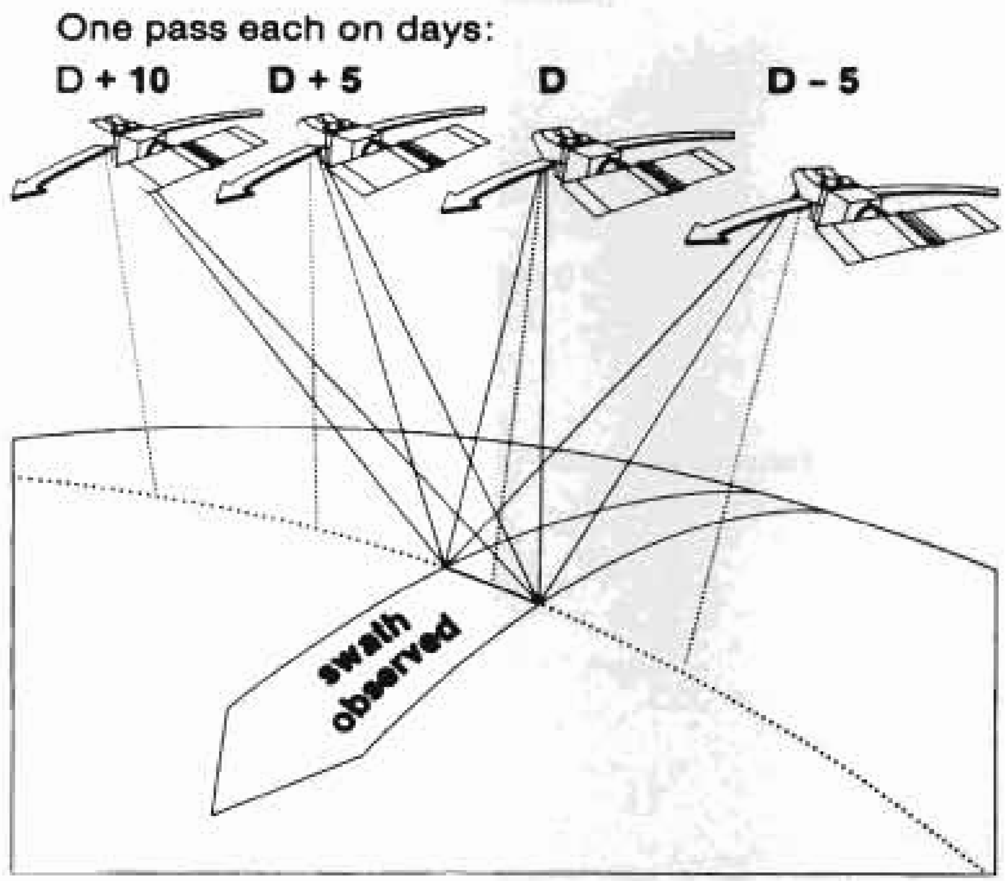
Acquisition flexibility of SPOT. When the two HRV instruments are operated in unison in the vertical viewing confirmation (i.e., when the payload is operated in the so called 'twin-vertical' configuration) the combined swath width, as measured on the ground, is 117 km



Acquisition flexibility of SPOT. The viewing capability of the SPOT HRV imaging instruments to either side of the satellite ground track gives imaging access to all areas within a 950 km wide corridor. This oblique or cross-track viewing capability considerably reduces the line required to obtain complete coverage of a country or to access a given area.



Excellent revisit capability of SPOT HRV. The oblique viewing capability of the SPOT imaging instruments ensures frequent opportunities for recording imagery of given areas of interest for study of the time-varying phenomena. At latitudes (such as those of continental France) the mean revisit frequency is once every 2.5 days, compared with once every 26 days if only vertical viewing takes place.



IRS-series

IRS-1A (1988)
IRS-1B (1991)
IRS-IC (1995)
IRS-1P (1994)

Indian Remote Sensing Satellite

IRS 1A/1B
Sun-synchronous orbit
Altitude = 904 km
Inclination angle = 99 degrees
Revisit cycle = 22 days
Period = 103 minutes

Sensors

LISS-I (Linear Imaging Scanner System - I)
0.45 - 0.52 µm
0.52 - 0.60 µm
0.63 - 0.69 µm
0.76 - 0.90 µm
IFOV = **73 m**
TFOV = 146 km (swath width)

LISS-II (Linear Imaging Scanner System - II)
0.45 - 0.52 µm
0.52 - 0.60 µm
0.63 - 0.69 µm
0.76 - 0.90 µm
IFOV = **36.5 m**
TFOV = 73 km x 2 (swath width)

ERS - series

ERS-1 (1991)
ERS-2 (1995)

European Remote Sensing Satellite (European Radar Satellite)

(European Space Agency (ESA))

Sun-synchronous orbit
Orbit altitude = 785 km
Inclination angle = 99 degrees
Revisit cycle = 3 days, 35 days, 176 days

Sensors: Three types of sensor

AMI (Active Microwave Instrumentation)
RA (Radar Altimeter)
ATSR/M (Along Track Scanning Radiometer / Microwave Sounder)

Sensor Characteristics of ERS Series

Sensor	Mode	Wavelengths / Frequency	IFOV	Swath Width
AMI	SAR mode	5.3 GHZ	30 m	100 km
AMI	wave mode	5.3 GHz	5km*5km	-
AMI	wind mode	5.3 GHz	50km	500 km
RA	-	13.8 GHz	-	-
ATSR / M	thermal IR	1.6 µm	1 km	500 km
ATST / M	thermal IR	3.7 µm	1 km	500 km
ATST / M	thermal IR	11 µm	1 km	500 km
ATST / M	thermal IR	12 µm	1 km	500 km
ATST / M	micro-wave sounder	23.8 GHz	22 km	-
ATST / M	micro-wave sounder	36.5 GHz	22 km	-

RADARSAT (Radar satellite)

Canada

RADARSAT-1 (1995 November 4)

Orbital elements:

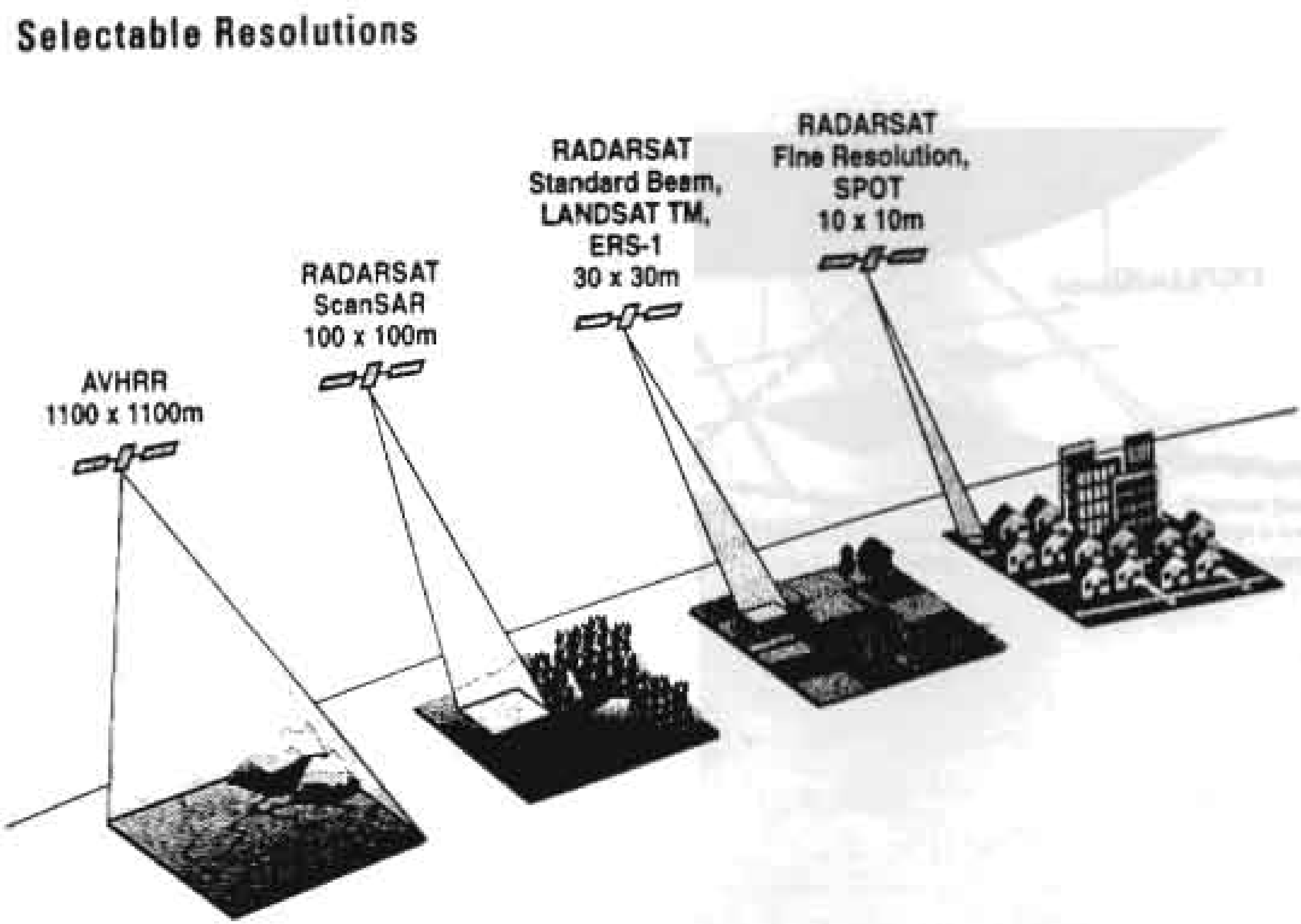
- Non-sun-synchronous
- Altitude = 793 km - 821 km
- Inclination = 99 degree
- Recurrent = 24 days
- Sensors = **SAR** (Synthetic Aperture Radar)
- Spectrum/Frequency = 5.3 Ghz (C band)

Sensor Name	IFOV	Swath Width (TFOV)
Standard Mode incident : 20 - 49 degrees	25m x 25m (4 looks)	100 km
Wide (1) Mode incident : 31 - 39 degrees	30 - 48m x 28m (4 looks)	165 km
Wide (2) Mode incident : 37 - 39 degrees	25 - 32m x 28m (4 looks)	150 km
Fine Resolution Mode incident : 37 - 48 degrees	9 - 11m x 9m (1 look)	45 km
Scan SAR (N) Mode incident : 20 - 49 degrees	50m x 50m (2 - 4 looks)	305 km
Scan SAR (W) Mode incident : 20 - 40 degrees	100m x 100m (4 looks)	510 km
Extended (H) Mode incident : 50 - 60 degrees	19 - 22m x 28m (4 looks)	75 km
Extended (H) Mode incident : 10 - 23 degrees	28 - 63m x 28m (4 looks)	170 km

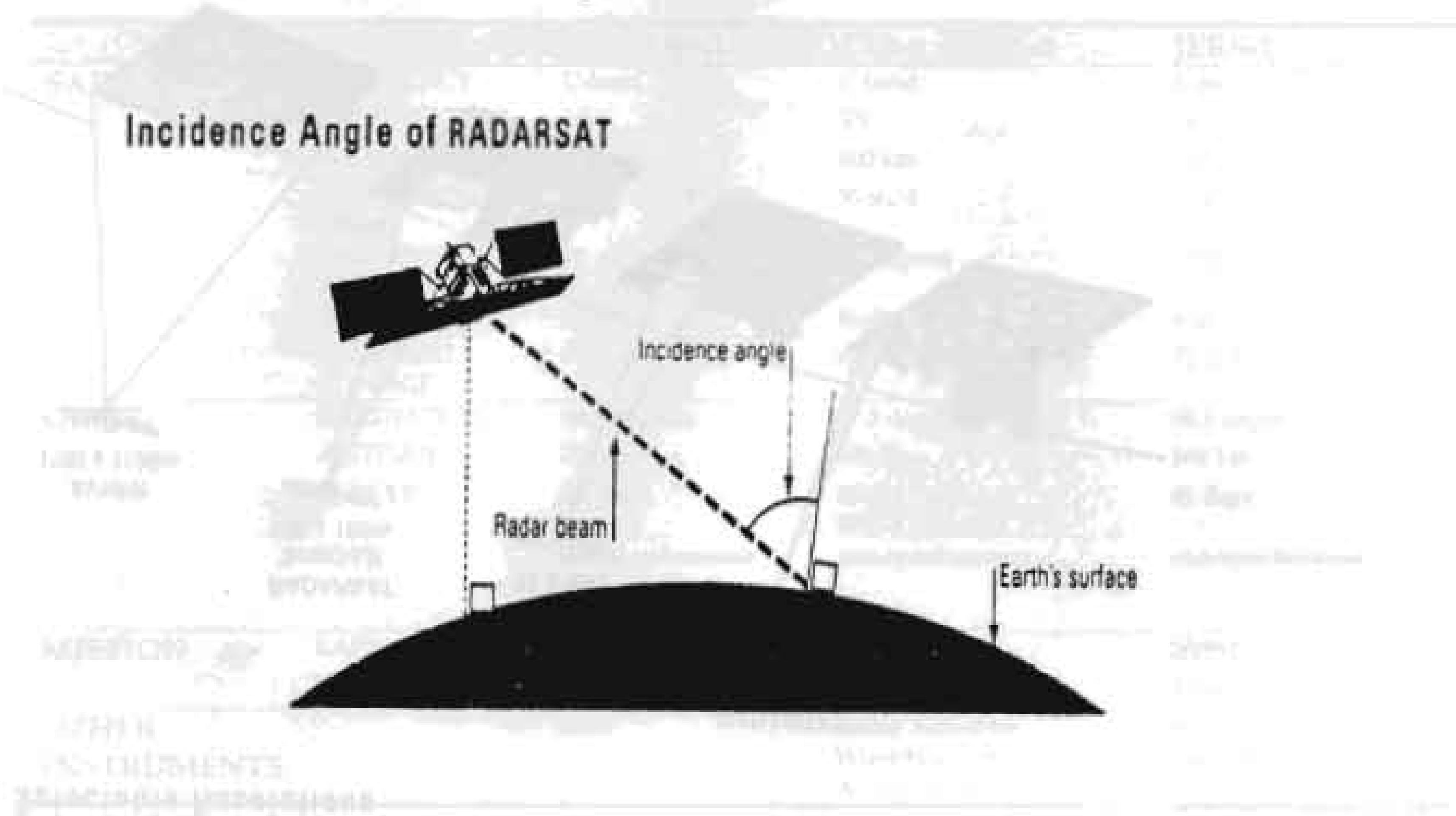
The SAR instrument characteristics for RADARSAT, ERS-1 & ERS-2, JERS-1

		RADARSAT	ERS-1 & ERS-2	JERS-1
SAR	*FREQUENCY*	C-band	C-band	L-band
	POLARISATION	HH	VV	HH
	SWATH	50 to 500 km	100 km	75 km
	RESOLUTION/ LOOKS	30 m/4 - 100m/8	30 m/4	30 m/4
	INCIDENCE ANGLE	20 - 50+ degrees	23 degrees	35 degrees
	ORIENTATION	Right	Right	Right
	ON-BOARD STORAGE	51 G bits	none	72 G bits
ORBIT	*INCLINATION*	98.6 degrees	97.5 degrees	98.5 degrees
	ALTITUDE	798 km	785 km	568 km
	REPEAT	**24 days**	**ERS-1 : various ERS-2 : 35 days**	**41 days**
	TYPE	**sun-synchronous dawn-dusk orientation**	**sun-synchronous**	**sun-synchronous**
MISSION	**LAUNCH**	**1995**	**1991; 1995**	**2/1992**
	LIFETIME	**5 years**	**2 -3 years +**	**2 years +**
OTHER INSTRUMENTS		**none**	**Radar Altimeter, Wind/Wave Scatterometer, Along-Track**	**Scanning Radiometer Optical Sensor**

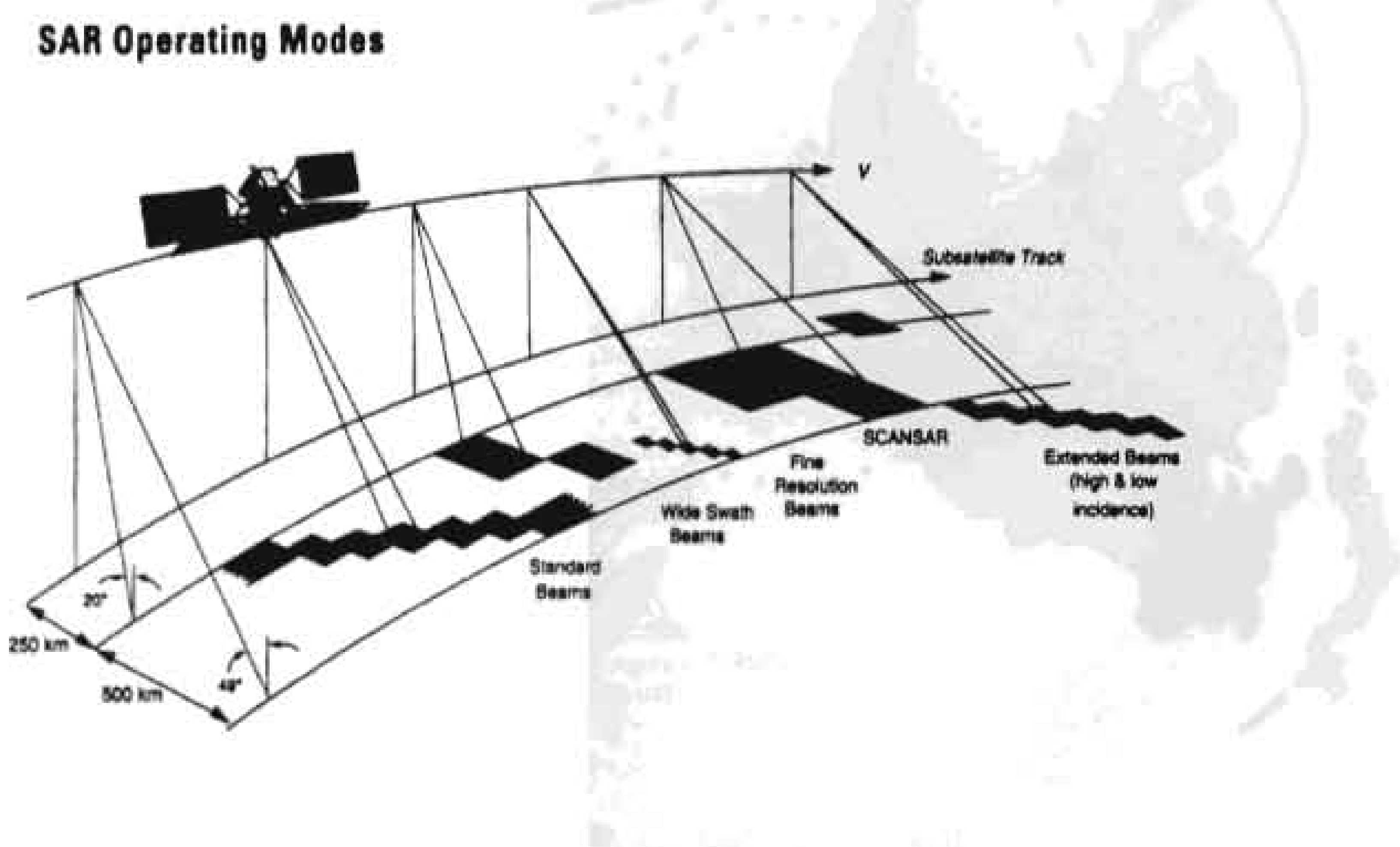
Selectable Resolutions of RADARSAT



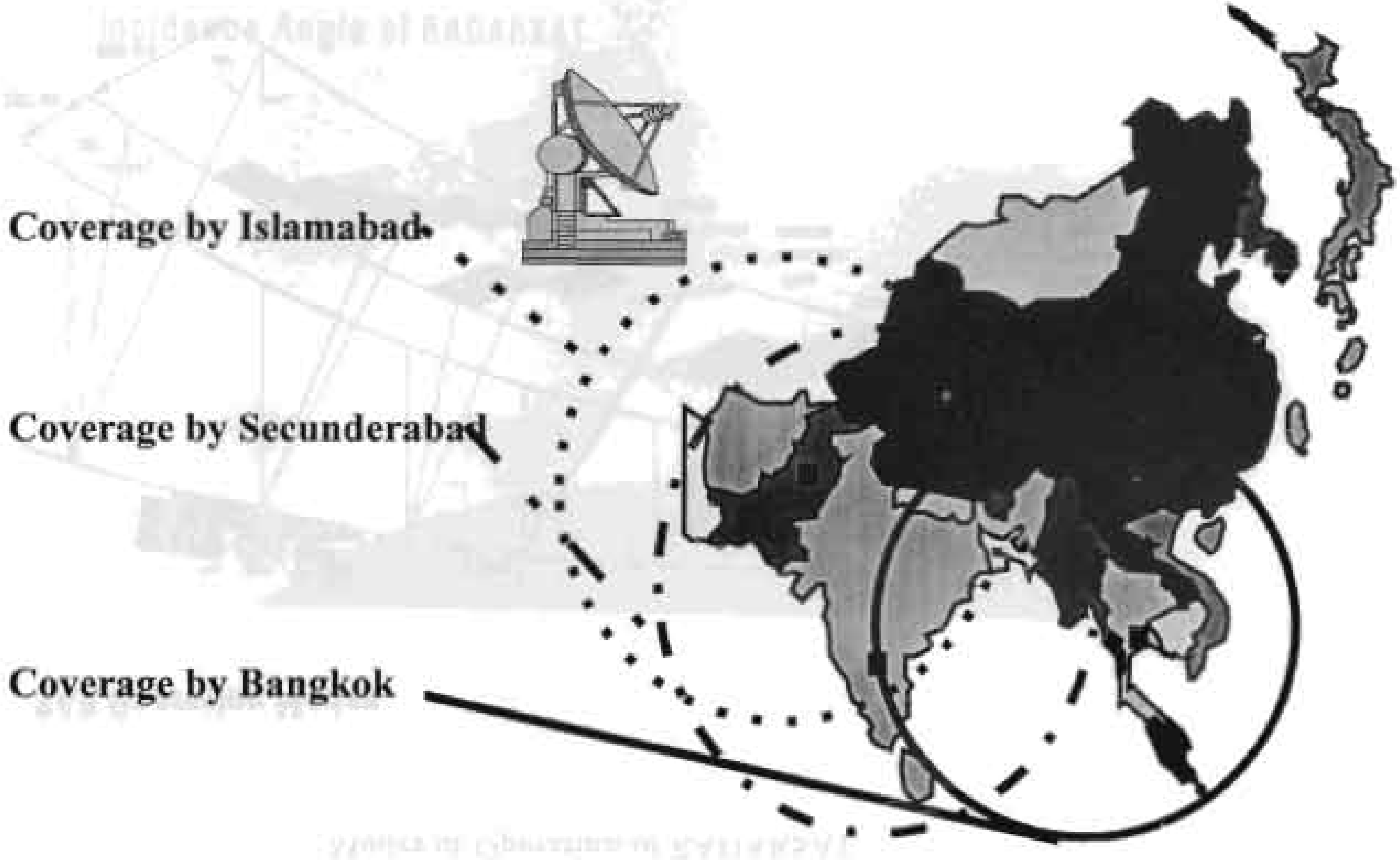
Incidence Angle of RADARSAT



Modes of Operation of RADARSAT



Ground Receiving Stations and Area Coverage



Ground Receiving Stations Covering HKH Region

LANDSAT

Bangkok (Thailand)
Secunderabad (India)
Islamabad (Pakistan)
Beijing (China)

SPOT

Bangkok (Thailand)
Secunderabad (India)

MOS

Bangkok (Thailand) Remote Sensing Division,
National Research Council of Thailand (NRCT),
196 Phahonyothin Road, Bangkhen,
Bangkok 10900, Thailand.
Tel. : 5791370 - 9

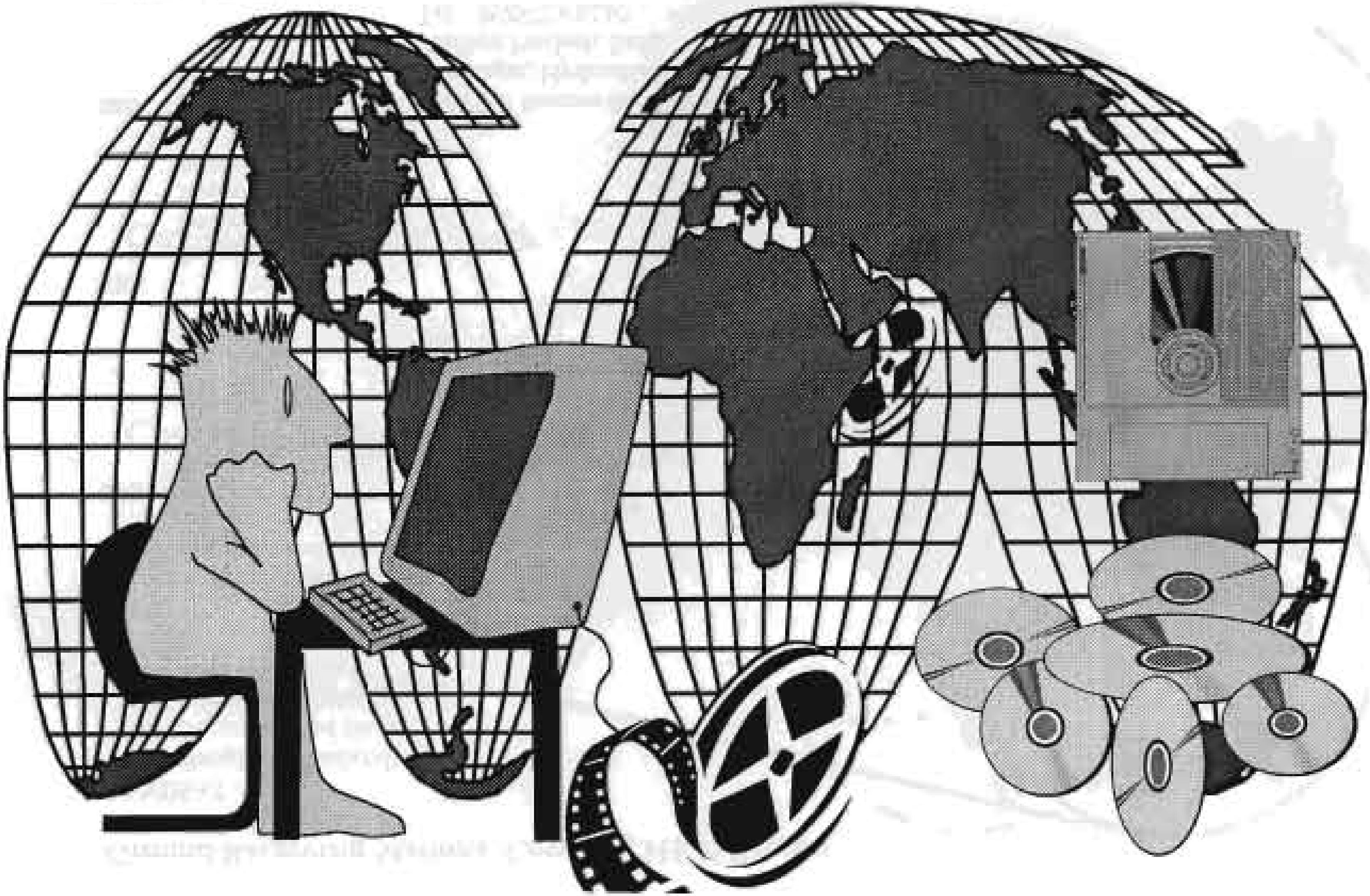
ERS

Bangkok (Thailand) ?
Secunderabad (India) ?
Islamabad (Pakistan) ?
Beijing (China) ?

IRS Secunderabad (India) National Remote Sensing Agency (NRSA),
Balanagar, Hyderabad - 500 037,
Andhra Pradesh, India.
Tel. : 262572 x 62,63

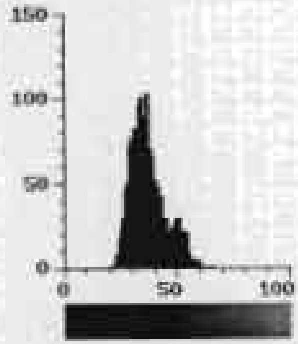
RADARSAT ???!!!

Digital Image Processing



THIS IS THE SPOT PANCHROMATIC IMAGE
OF THE KATHMANDU AREA ON 05 MAY 1991

A. GRAY -SCALE IMAGE



THIS IS THE HISTOGRAM OF THE SUBSET (40 * 40)
(FROM ORIGINAL DATA WITHOUT STRETCHING)

B. HISTOGRAM AND GRAY SCALE

GRAY-SCALE IMAGE OF [illegible] AREA
05 MAY 1991 SPOT PAN 10 METER RESOLUTION

Column Number

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	32	30	34	31	31	34	35	35	32	30	30	32	33	33	36	45	45	37	35	36	37	39	42	44	44	43	40	39	38	37	32	27	28	26	26	30	35	34	33	37
2	32	33	32	31	32	35	34	36	40	35	32	31	32	34	35	44	46	41	35	36	37	37	39	41	42	41	42	41	40	37	30	25	23	25	25	28	36	38	37	43
3	29	29	31	29	36	35	29	33	37	33	29	35	34	33	33	38	46	42	37	35	35	37	38	38	38	37	38	40	38	29	24	23	23	24	26	25	30	36	36	39
4	32	30	31	31	36	36	38	39	34	30	34	37	42	39	35	37	45	46	39	37	38	37	39	38	38	38	40	40	36	29	24	24	26	27	28	31	32	34	37	39
5	34	31	32	30	34	33	35	37	30	31	33	37	48	42	37	34	42	45	42	37	38	40	41	40	38	38	39	40	35	28	24	25	28	28	29	30	31	34	38	39
6	33	31	32	36	39	33	33	36	31	32	37	39	44	42	41	37	41	46	45	45	45	43	43	39	39	44	50	45	38	31	29	30	31	29	29	31	33	35	36	37
7	30	28	31	34	37	31	27	27	27	28	32	31	28	29	37	33	36	45	44	40	37	48	53	53	51	54	57	55	43	32	29	32	31	26	28	28	29	38	40	34
8	31	30	35	40	36	32	30	26	28	34	35	31	32	29	35	33	34	44	44	38	44	54	57	57	55	56	59	58	52	41	35	34	32	31	31	31	32	36	40	33
9	33	30	37	40	38	38	32	28	29	28	28	28	29	30	34	36	34	39	46	48	58	56	52	52	50	50	52	52	52	50	43	37	32	29	34	32	30	26	34	37
10	37	30	32	34	33	34	32	30	30	31	31	30	34	30	41	42	35	36	46	39	58	51	50	47	46	46	51	51	50	51	51	44	38	33	33	33	30	30	37	42
11	31	30	29	30	31	31	31	30	30	32	35	31	28	35	44	43	37	34	44	54	53	49	45	39	39	41	43	50	51	50	50	47	41	32	29	29	34	40	41	41
12	33	34	33	33	30	31	32	33	33	35	34	32	38	44	45	42	41	39	42	48	49	48	43	44	45	47	49	49	53	53	53	52	48	40	36	43	48	41	38	37
13	33	37	40	38	35	33	34	40	35	31	30	31	35	38	32	33	39	40	38	37	47	48	44	47	49	49	47	49	50	52	51	52	51	46	45	45	45	41	37	35
14	34	43	53	47	38	32	32	34	28	27	27	27	30	29	31	34	38	36	32	38	49	50	46	47	50	53	51	49	50	53	54	52	52	49	44	43	42	42	39	43
15	36	42	45	40	33	29	30	27	24	24	27	28	28	27	32	40	39	31	28	31	43	49	46	45	46	50	51	50	47	50	52	49	49	46	41	35	36	39	44	53
16	33	34	36	35	32	32	30	28	28	27	28	30	28	26	30	39	40	33	28	30	41	50	49	47	49	53	54	52	51	51	53	52	51	50	45	38	35	37	43	49
17	30	33	33	32	34	32	29	30	30	28	30	29	29	30	32	35	37	37	33	36	41	48	51	48	48	50	53	54	51	48	49	50	49	49	44	36	33	35	40	45
18	32	33	37	40	40	36	31	34	35	35	31	27	28	34	31	32	32	36	35	37	40	48	52	52	50	54	55	54	53	51	49	51	50	48	48	41	37	39	43	45
19	29	35	34	38	42	39	29	28	34	29	25	22	24	27	25	29	20	36	37	35	38	43	50	54	51	50	51	51	51	49	47	48	48	46	41	41	43	39	35	35
20	32	33	37	37	34	32	27	28	32	27	25	25	26	28	30	37	33	36	42	39	36	42	47	54	55	54	51	52	55	52	48	48	48	43	40	42	41	34	28	30
21	43	41	32	33	37	36	32	27	27	25	28	29	30	35	36	42	33	33	40	38	34	37	44	50	54	52	52	53	53	50	46	43	45	41	36	36	33	29	28	30
22	42	37	35	39	46	54	43	35	31	34	34	34	34	37	39	37	37	36	43	41	39	40	42	48	54	55	54	53	55	51	44	41	44	40	36	37	34	34	35	35
23	29	29	32	43	49	56	49	38	33	32	37	38	31	35	35	36	36	39	45	43	42	45	42	43	51	53	53	53	53	48	41	42	39	38	34	35	36	36	36	38
24	36	39	42	44	41	36	39	38	32	34	33	38	36	34	38	37	33	37	42	43	41	50	49	48	55	59	56	54	54	49	40	42	36	34	36	38	30	36	35	37
25	42	43	38	33	30	30	32	35	35	35	33	36	32	33	38	33	33	34	33	36	39	47	60	54	52	51	45	43	43	42	38	33	51	33	38	30	37	37	36	38
26	34	36	35	29	27	32	35	37	37	34	33	34	35	37	35	31	31	28	30	30	36	47	57	60	53	44	35	36	38	37	34	34	34	40	43	39	38	37	37	41
27	30	33	30	27	29	31	32	36	34	31	37	40	41	38	32	30	28	27	25	28	33	41	51	59	57	46	37	36	36	35	35	39	44	42	39	40	43	36	34	33
28	32	33	30	28	36	34	30	30	30	30	36	43	41	36	29	23	25	29	33	33	36	40	47	55	54	51	44	47	46	42	41	42	44	38	41	45	45	40	37	36
29	33	31	31	33	35	34	29	27	29	31	34	35	33	31	27	23	24	28	32	36	43	42	43	45	42	38	38	38	36	34	34	39	40	38	39	37	37	39	37	33
30	30	31	34	34	37	37	35	34	35	33	31	34	35	34	31	27	26	27	29	33	42	42	42	43	43	41	37	33	30	31	33	37	36	32	31	29	34	39	36	31
31	38	33	30	28	32	36	33	29	30	31	27	24	27	29	28	30	33	33	32	36	39	39	38	40	41	37	33	32	34	37	36	35	33	31	28	33	37	35	36	31
32	39	40	38	35	39	39	31	25	25	26	24	24	24	25	27	29	32	38	41	40	40	40	40	42	42	38	33	35	35	35	36	34	29	27	30	32	31	30	33	35
33	35	35	34	38	44	37	27	23	23	25	24	22	21	22	24	25	30	39	38	33	37	37	34	37	40	37	33	29	30	30	30	32	28	28	29	29	27	28	31	34
34	37	34	30	38	43	38	31	27	28	29	25	25	27	27	27	26	28	41	40	29	31	38	33	31	38	42	37	32	33	31	29	29	29	33	34	28	28	33	34	35
35	37	32	32	38	51	48	39	27	25	34	26	23	26	26	26	24	28	32	37	32	31	39	37	34	34	35	38	37	32	29	30	29	30	32	28	27	32	36	32	30
36	36	37	36	46	60	52	54	36	33	44	38	26	27	27	26	26	26	29	31	31	37	48	43	38	34	33	33	39	40	37	34	33	32	29	29	29	31	29	28	31
37	36	35	36	49	60	35	66	38	35	48	46	30	27	27	26	26	27	26	27	28	38	46	37	31	32	34	34	32	34	36	37	34	31	27	28	33	31	27	30	32
38	34	37	39	46	65	51	54	33	39	50	40	31	33	31	28	27	26	31	34	36	41	43	40	37	38	39	39	36	31	36	40	38	32	29	31	30	28	32	35	34
39	37	37	43	45	61	48	50	34	34	40	33	36	39	34	28	24	28	34	35	38	42	38	42	42	37	39	39	35	31	34	36	37	36	32	29	29	28	28	30	33
40	38	40	41	42	58	47	50	34	41	44	42	41	43	37	28	25	28	34	35	43	42	32	38	47	40	33	33	33	34	36	35	37	37	40	38	30	28	26	31	34

ARRAY OF DNs FOR THE SPOT PANCHROMATIC IMAGE OF 05 MAY 1991 WITH 10 METRE RESOLUTION

The **pixel** or 'picture element' is a data element having both spatial and spectral aspects. The spatial variable defines the apparent size of the resolution cell (i.e., the area on the ground represented by the data values), and the spectral variable defines the intensity of the spectral response for that cell in a particular channel. The pixel is also referred to as resolution cell of a scene which is considered as the smallest area in a scene, considered a unit of data. Information conveyed by the spectral response of individual resolution cells in the scene is spectral information. The position of any pixel is determined on an x-y coordinate system. Each pixel has a numerical value called a digital number (DN) that records the intensity of electro-magnetic energy measured for the ground resolution cell represented by that pixel. Digital numbers range from zero to some higher number on a gray scale depending upon the quantization level of the sensor.

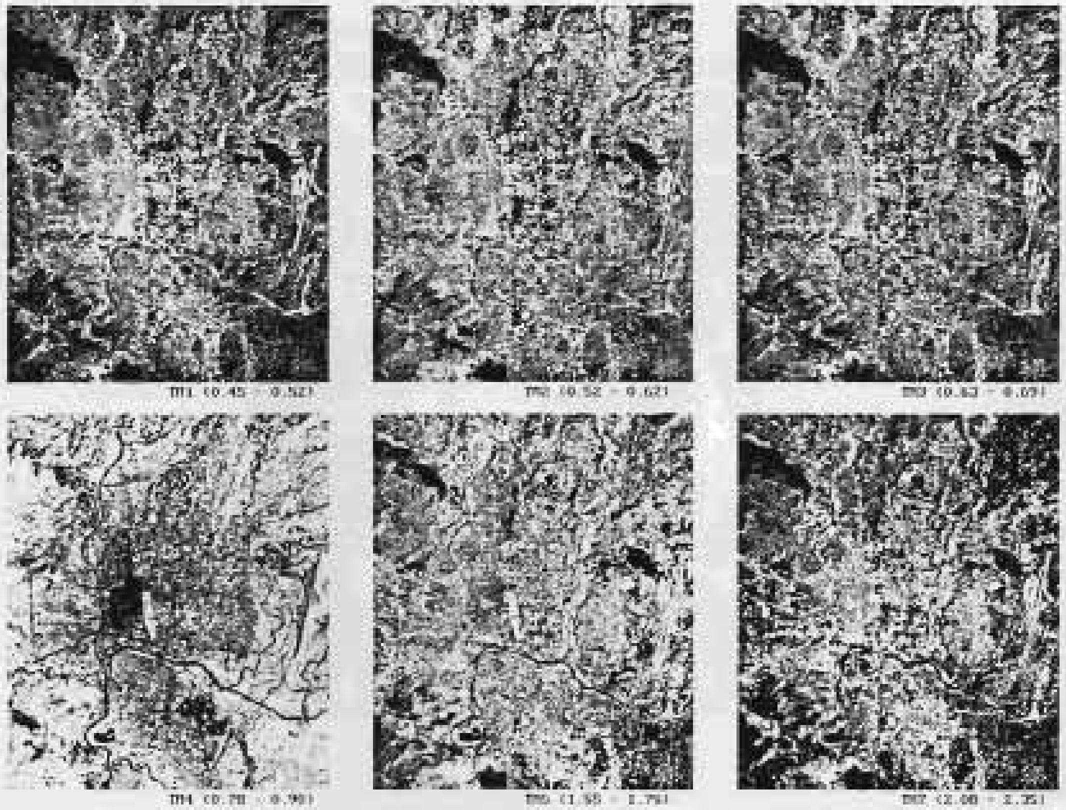
The **gray scale** is a sequence of gray tones ranging from black to white. Gray-level value is the intensity value of a pixel in a gray-level image.

The **histogram** is the graphical display of a set of data showing the frequency of occurrence (along the vertical axis) of individual measurements or values (along the horizontal axis); a frequency distribution.

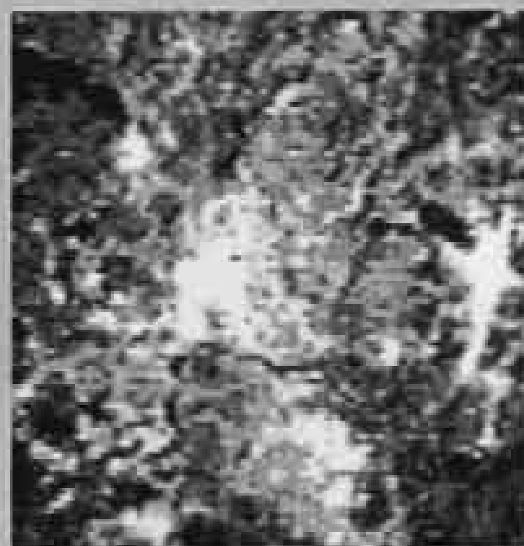
The **scene,** in a passive remote sensing system, is everything that occurs spatially or temporally before the sensor, including the earth's surface, the energy source, and the atmosphere which the energy passes through as it travels from its source to the earth and from the earth to the sensor.

The **image** is the pictorial representation of a scene recorded by a remote-sensing system irrespective of the wavelength or imaging device used to produce it. Although image is a general term, it is commonly restricted to representations acquired by non-photographic methods. A photograph is also an image that records wavelengths of from 0.3 to 0.9 micrometres and which have interacted with light-sensitive chemicals in a photographic film. Images can be described in terms of certain fundamental properties regardless of the wavelength at which the image is recorded. These common fundamental properties are scale, brightness, contrast, and resolution. Tone and texture of images are functions of the fundamental properties. The image may be described in strictly numerical terms on a three-coordinate system with x and y locating each pixel and z giving the digital number (DN), which is displayed as a gray-scale intensity value. In a remote-sensing system, images are, in general, originally recorded in digital format (e.g., Landsat). An image recorded initially on photographic film or prints may be converted into digital format by a process known as digitisation (scanning).

SPOT PAN PANCHROMATIC MODE 20 DEC 1988 KATHMANDU NEPAL
(10 m RESOLUTION) 0.5 to 0.7 micrometers



LANDSAT TM DATA 11 OCT 1988 KATHMANDU NEPAL



TM6 (10.4 - 12.5)

LANDSAT TM BAND6 (THERMAL BAND)

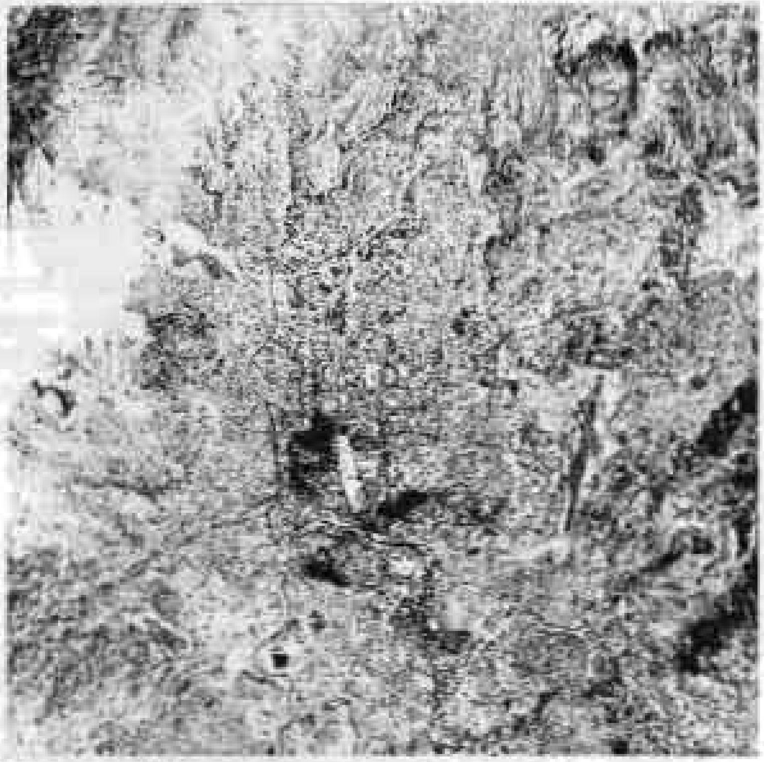
11 OCT 1988 KATHMANDU NEPAL

A **digital image** is a numerical representation of a sampled field. Typically, the field represented is the radiance of a scene viewed in some region of the electro-magnetic spectrum. Thus, a digital image is an image f(x,y) which has been described both in spatial coordinates and in brightness. We may consider a digital image as a matrix whose row and column indices identify a point in the image and the corresponding matrix element identifies the gray level at that point. However, digital images can be constructed that describe gravity or magnetic field strength, topographic relief, or computed variables such as thermal inertia. The digital image is generated by sampling and measuring the local field strength as a number of points that are usually arranged in a rectilinear pattern. The field strength measured at each of these points is encoded as an integer. Thus, the digital image is actually an array of numbers which can be stored on magnetic tape or disk. In this form, the digital image cannot be inspected visually, but it can be manipulated readily by a digital computer.

Digital image processing is the manipulation of a digital image by computer and is performed either to prepare an image for display and interpretation, or to extract information from the image.

SPOT2 HRV2 XS1 BAND1 (0.50 - 0.59) K 224 J 294 05 MAY 1991 KATHMANDU NEPAL


SPOT2 HRV2 XS2 BAND2 (0.62 - 0.68) K 224 J 294 05 MAY 1991 KATHMANDU NEPAL



In general, digital image processing consists of the following procedures.

DIGITAL IMAGE PROCESSING

- *CORRECTION*
  - RADIOMETRIC CORRECTION
  - ATMOSPHERIC CORRECTION
  - GEOMETRIC DISTORTIONS OF THE IMAGE
    - GEOMETRIC CORRECTION
      - Geometric transformation
      - Collinearity equation
      - Resampling equation
      - Map projection
      - ......
- *CONVERSION*
  - IMAGE ENHANCEMENT
    - Gray scale conversion
    - Histogram conversion
    - Colour composite
    - Colour conversion between RGB and HSI
    - ...
  - FEATURE EXTRACTION
    - SPECTRAL FEATURES
      - Special colour or tone
      - Gradient
      - Spectral parameter
      - ...
    - GEOMETRIC FEATURES
      - Edge
      - Linearment
      - Shape
      - Size
      - ...

contd...

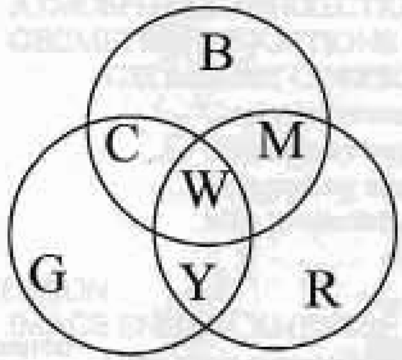
- TEXTURAL FEATURES
  - Pattern
  - Spatial frequency
  - Homogeneity
- *CLASSIFICATION*

Elements (Keys) of Image Interpretation

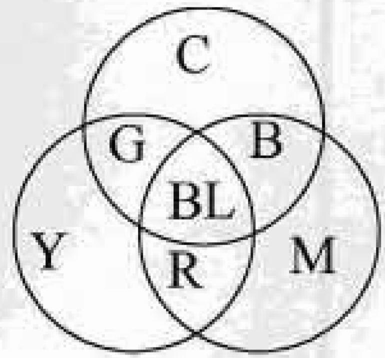
The following eight elements are mostly used in image interpretation

- Colour
- Tone
- Texture
- Pattern
- Shape
- Size
- Shadow
- Association

Methods of Colour Composite



Additive colour composite



Subtractive colour composite

B = Blue
G = Green
R = Red
W = White

C = Cyan
M = Magenta
Y = Yellow
BL = Black

METHODS OF COLOUR COMPOSITE

Colour

Colour display of remote-sensing data is of importance for effective visual interpretation.

There are two colour display methods: **colour composite**, to generate colour with multi-band data, and **pseudo-colour display**, to assign different colours to the grey scale of a single image.

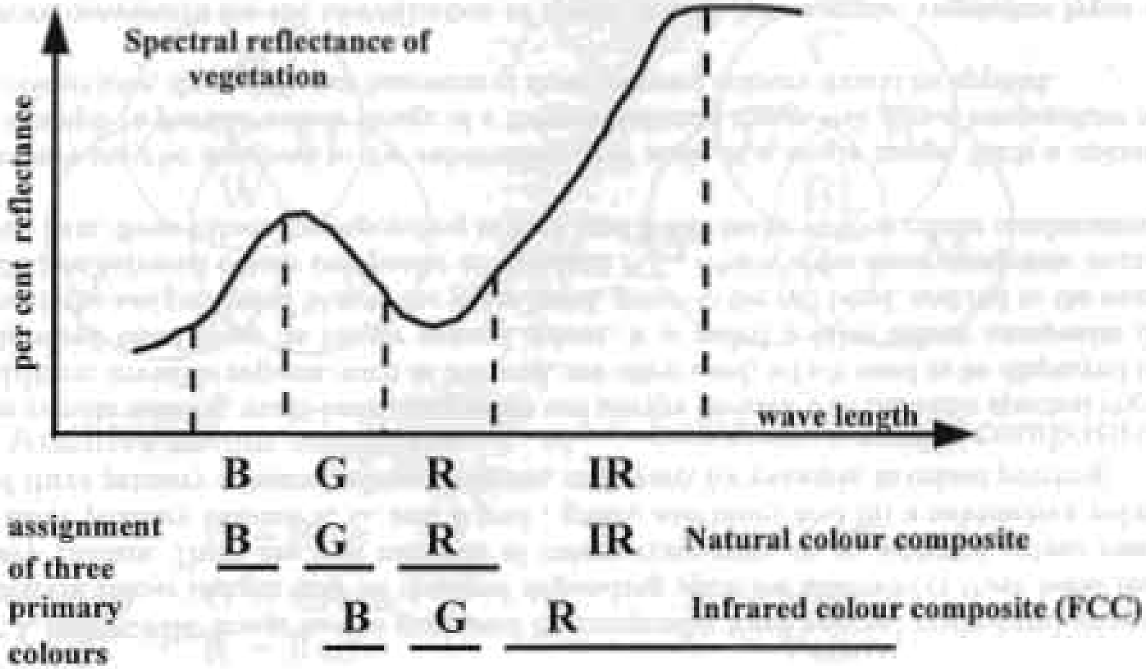
A **Colour Composite** image can be generated by composing three selected multi-band images with the use of three primary colours. Different colour images may be obtained depending upon the selection of three band images and the assignment of the three primary colours. There are two methods of colour composite: (i) an **additive colour composite** which **uses three light sources of three primary colours** R, G, and B (red , green, and blue), and (ii) a **subtractive colour composite** which **uses three pigments of three primary colours** (yellow, magenta, and cyan), for example, in colour printing.

However, in remote sensing, multi-band images are not always divided into the same spectral regions as the three primary colour filters. In addition, invisible regions, such as infrared, are often used, which need to be displayed in colour. As a colour composite within an infrared band is no its longer natural colour, it is called a **false colour composite (FCC).** In particular, the colour composite with the assignment of blue to the green band, green to the red band, and red to the near infrared band is very popular, and it is called an **infrared colour composite** or standard FCC, which is the same composite found in infrared colour film. In the case of digital data, three values corresponding to R, G, and B will make various colour combinations.

Different colours may be assigned to the subdivided gray scale of a single image. Such a colour allocation is called a pseudo-colour. For example, a **pseudo-colour image** of a thermal infrared image will give a temperature map. If one wishes to produce a continuous colour tone, three different functions of three primary colours should be applied.

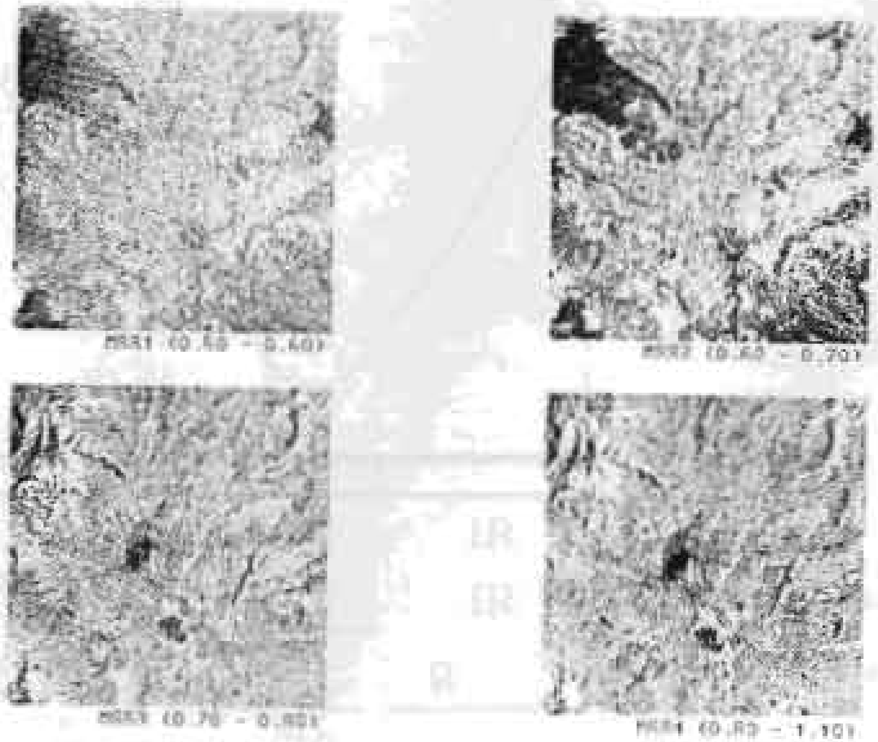
Colour is more convenient for the identification of object details. For example, vegetation types and species can be more easily interpreted by less experienced interpreters using colour information. Sometimes colour infrared photographs or false colour images will give more specific information, depending upon the emulsion of the film or the filter used and the object being imaged. To understand the colour of features on an image, one should keep in mind what colour combination was used to make that colour composite image and the spectral reflectance curves for those features.

Examples of Colour Composites

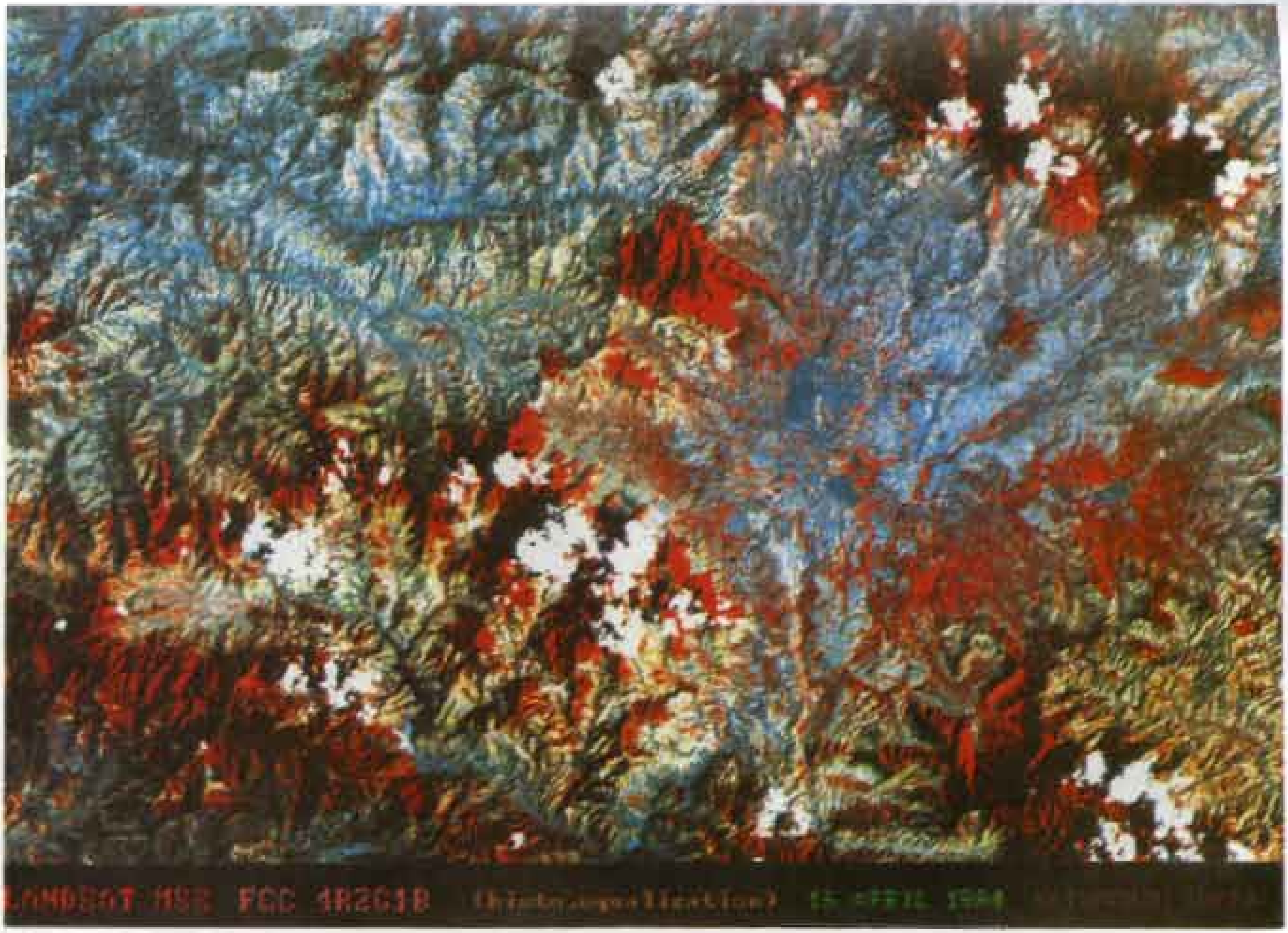


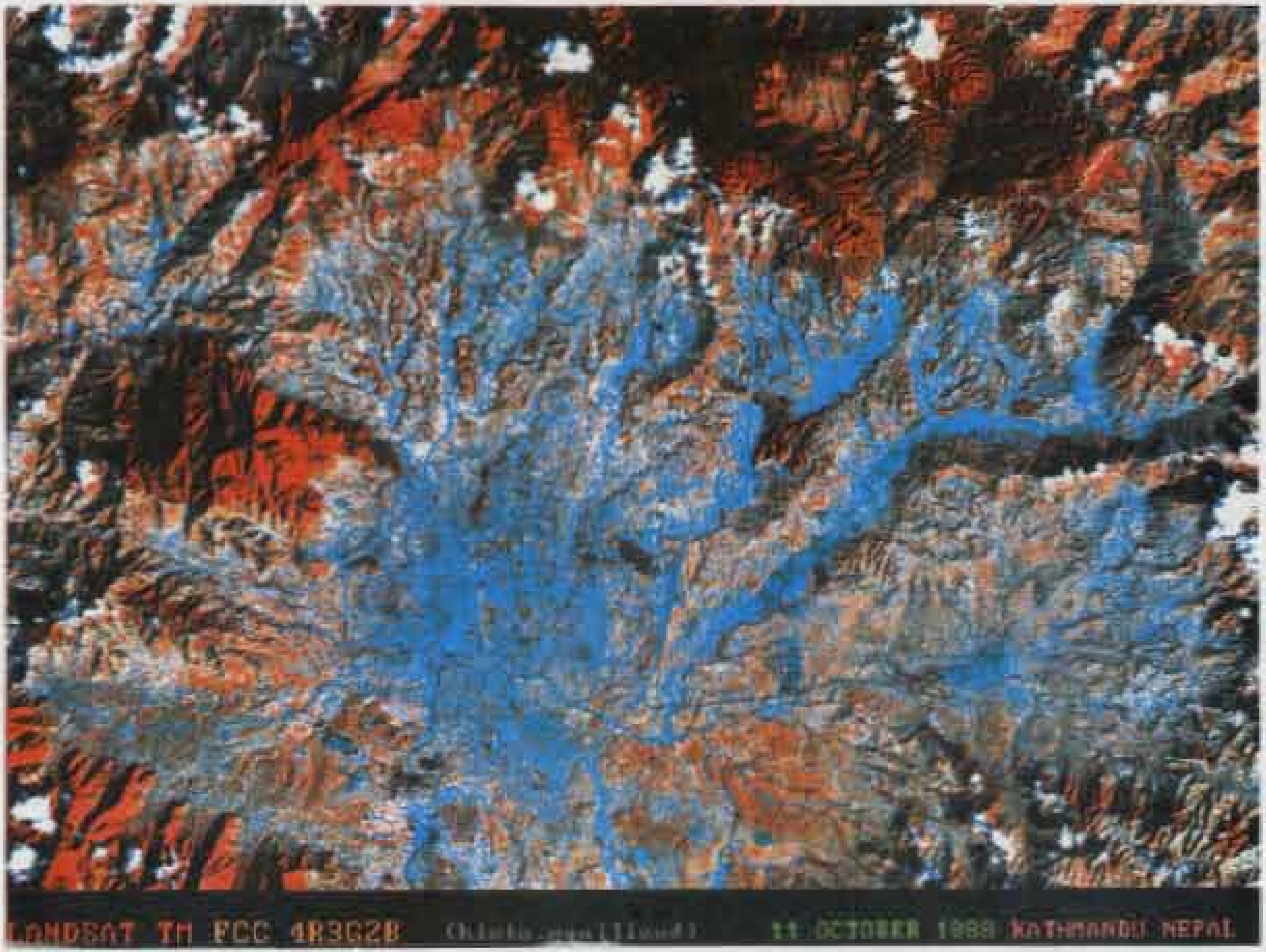
Samples of Colour Composites from Digital Data

Blue	Green	Red	Colour
0	0	0	Black
127	127	127	Grey
255	255	255	White
255	0	0	Blue
0	255	0	Green
0	0	255	Red
255	255	0	Cyan
255	0	255	Magenta
0	255	255	Yellow



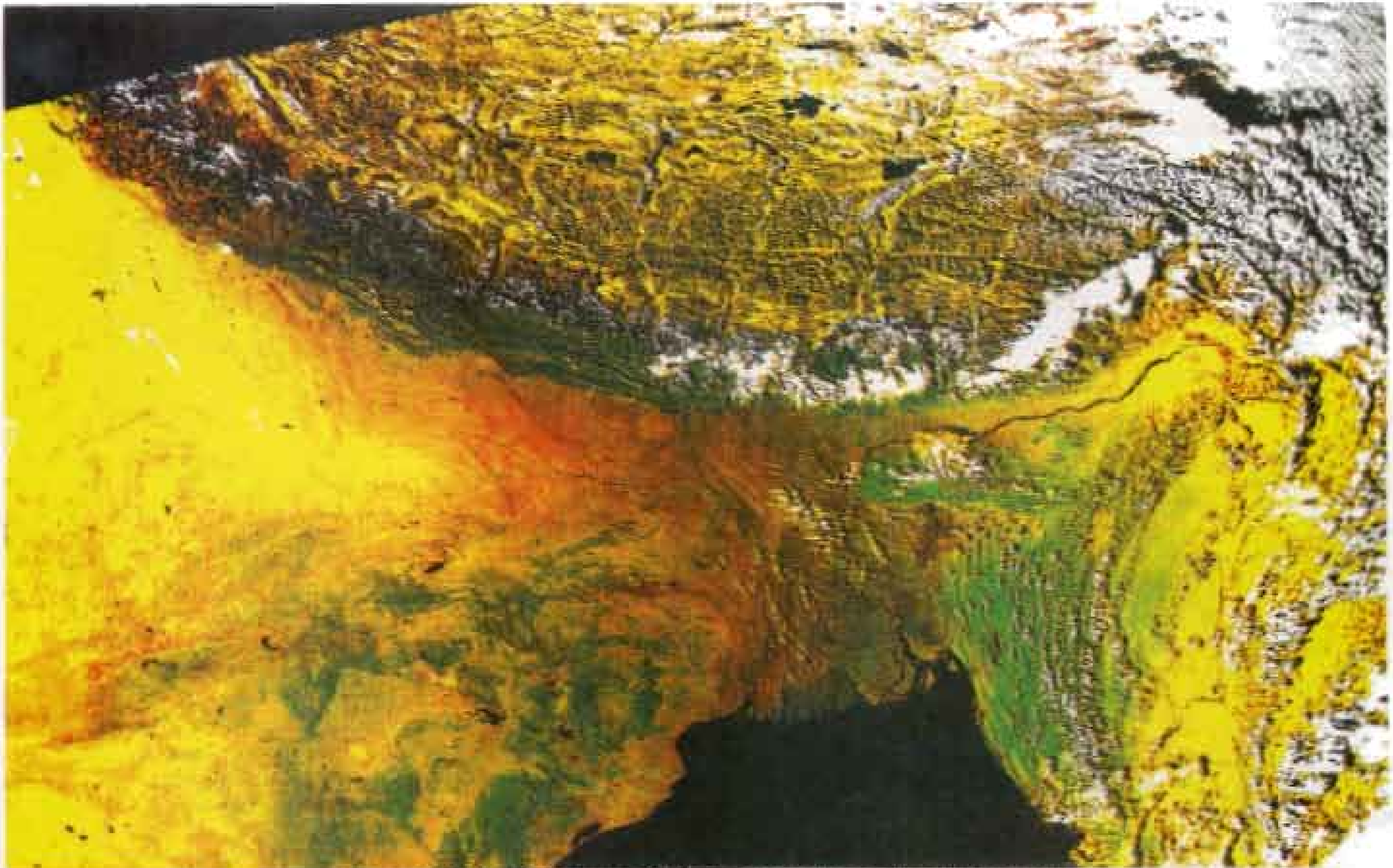
LANDSAT MSS IMAGES


LANDSAT MSS FCC 4R2G1B


LANDSAT TM FCC 4R3G2B
11 OCTOBER 1988 KATHMANDU NEPAL


05 MAY 1991


IRS1A
LISS
FCC 4R3G1B
KATHMANDU



NOAA-AVHRR 11 DEC 1993 COLOUR COMPOSITE R:Ch1 G:Ch2 B:NDVI

Tone

The continuous gray scale varying from white to black is called tone. In panchromatic photographs, any object will reflect its unique tone according to the reflectance. For example, dry sand reflects white, while wet sand reflects black. In black and white near infrared photographs, water is black and healthy vegetation white to light gray. Tone denotes the spectral reflectance of the features.

Texture

Texture is a group of repeated small patterns. For example, homogeneous grassland exhibits a smooth texture, coniferous forest usually show a coarse texture. However, this will depend upon the scale of the photograph or image.

Pattern

Pattern is a regular, usually repeated, shape in respect to an object. For example, rows of houses or apartments, regularly-spaced rice fields, interchanges of highways, orchards, and so on, can provide information from their unique patterns.

Shape

The specific shape of an object, as it is viewed from above, will be imaged on a vertical photograph. Therefore, the shape from a vertical viewpoint should be known. For example, the crown of a conifer tree looks like a circle, while that of a deciduous tree has an irregular shape. Airports, factories, and so on can also be identified by their shapes.

Size

A proper photo-scale (image resolution) should be selected depending on the purpose of the interpretation. The approximate size of an object can be measured by multiplying the length of the image by the inverse of the photo-scale.

Shadow

Shadow is usually a visual obstacle for image interpretation. However, shadow can also give height information about a tower, tall building, mountain ranges, and others, as well as shape information from the non-vertical perspective-such as the shape of a bridge.

Association

A specific combination of elements, geographic characteristics, and configuration of the surroundings, or the context, of an object can provide the user with specific information for image interpretation.

Interpretation Keys for Forestry

Species	Crown Shape	Edge of Crown	Tone	Pattern	Texture
cedar	conical with sharp spear	circular and sharp	dark	spotted grain	hard and coarse
cypress	conical with rounded crown	circular but not sharp	dark but lighter than cedar	spotted	hard and fine
pine	cylindrical with shapeless crown	circular but unclear	light and unclear	irregularly spotted	soft but coarse
larch	conical with unclear crown	circular but unclear edge	lighter than cypress	spotted	soft and fine
fir/spruce	conical with wider crown	circular with zigzag edge	dark and clear	irregular	coarse
deciduous	irregular shapes	unclear	lighter	irregular	coarse

A Sample of Landsat MSS Images' Interpretation Key

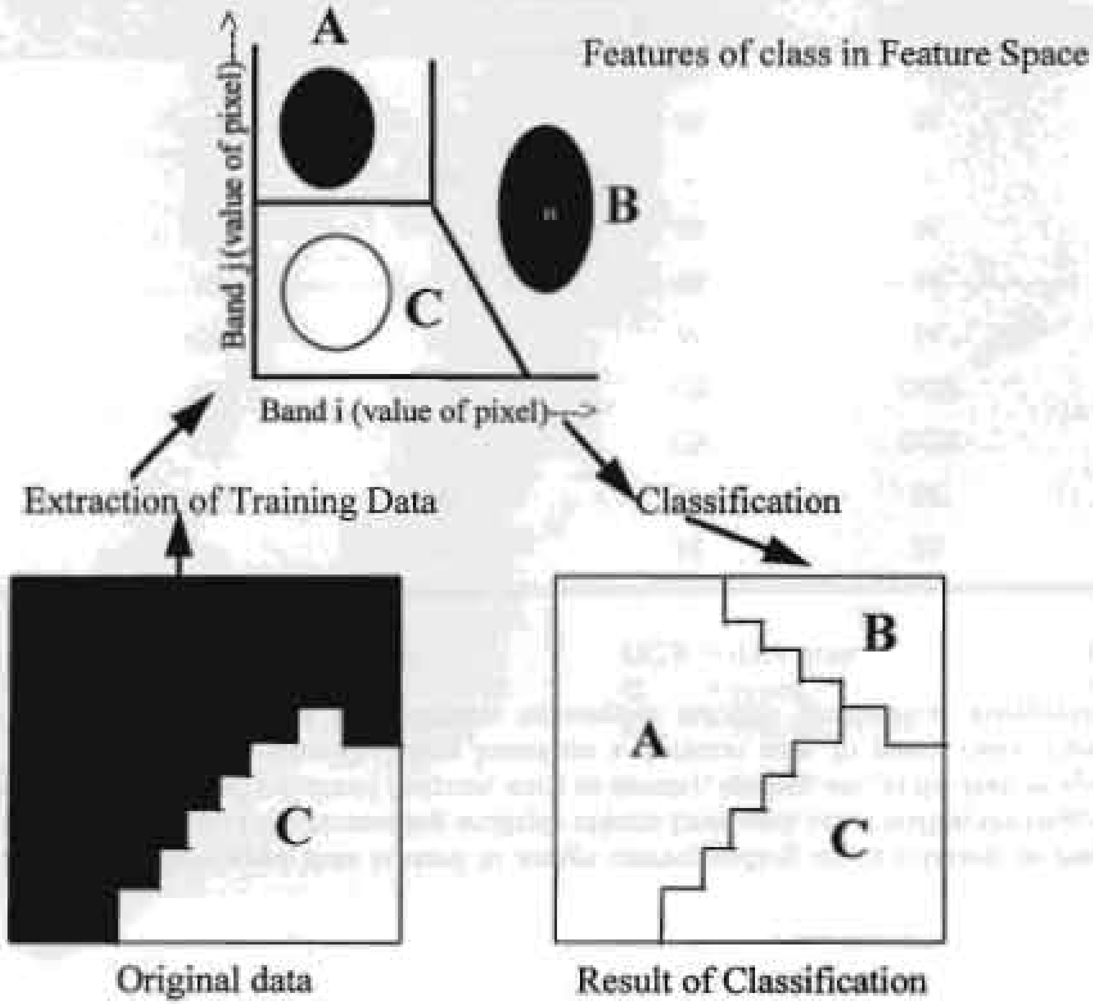
	Band 4	Band 5	Band 6	Band 7	457 (BGR)	456 (RGB)
snow	PW	PW	PW	PW	PW	PW
cloud	W	W	W	W	W	W
haze	W	W	-	-	W	W
forest	DGR	BL	W	W	R	G
grass	FR	DG	W	W	P	BY
bare land	GR	W	W	W	W	W
wet land	GR	W	GR	DGR	LB	RP
urban	GR	W	GR	DGR	LB	RP
water	DGR	BL	BL	BL	B	BP
shadow	BL	BL	BL	BK	BL	BL

PW = pure white
BL = black
BY = brownish yellow
BP = bluish purple
W = white
R = red
LB = light blue
DGR = dark gray
G = green
RP = reddish purple
GR = gray
P = pink

Classification

Classification of remotely-sensed data is used to assign corresponding levels (classes) in respect to groups with homogeneous characteristics, with the aim of discriminating multiple objects from each other within the image. Classification will be executed on the base of spectral or spectrally-defined features, such as density, texture, etc, in the feature space. It can be said that classification divides the feature space into several classes based on a decision rule. In many cases, classification can be undertaken on a computer, by using mathematical classification techniques through geometrical interpretation of pattern recognition using discriminant functions.

Concept of Classification of Remote-Sensing Data



Procedures of Classification

Classification will be carried out under the following procedures.

1. **Definition of classification classes**: Depending on the objective and on the characteristics of the image data, the classification classes should be clearly defined.

2. **Selection of features**: Features to discriminate between the classes should be established using multi-spectral and/or multi-temporal characteristics, textures, etc.

3. **Sampling of training data**: Training data should be sampled in order to determine appropriate decision rules. Classification techniques, such as supervised or unsupervised learning, will then be selected on the basis of the training data sets.

   - Supervised learning
   - Unsupervised learning

4. **Estimation of universal statistics**: Various classification techniques will be compared with the training data, so that an appropriate decision rule is selected for subsequent classification.

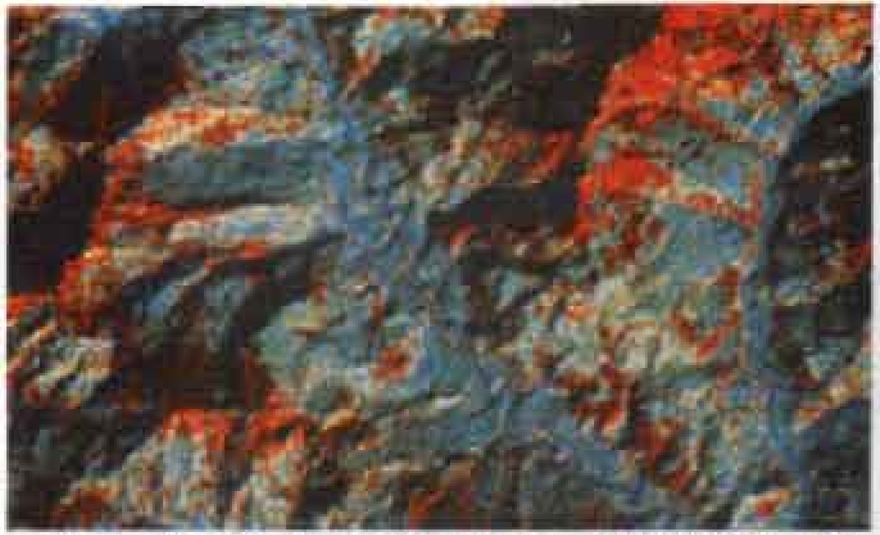
   - Proper decision rule

5. **Classification**: Depending upon the decision rule, all pixels are classified into a single class. There are two methods of pixel by pixel classification and per field classification in respect to segmented areas.

   Popular techniques are as follow:
   i. multi-level slice classifier (parallel-piped classifier),
   ii. decision tree classifier,
   iii. minimum distance classifier,
   iv. maximum likelihood classifier, and
   v. other classifiers such as fuzzy theory and expert system.

6. **Verification of results**

The classified results should be checked and verified for their accuracy and reliability.

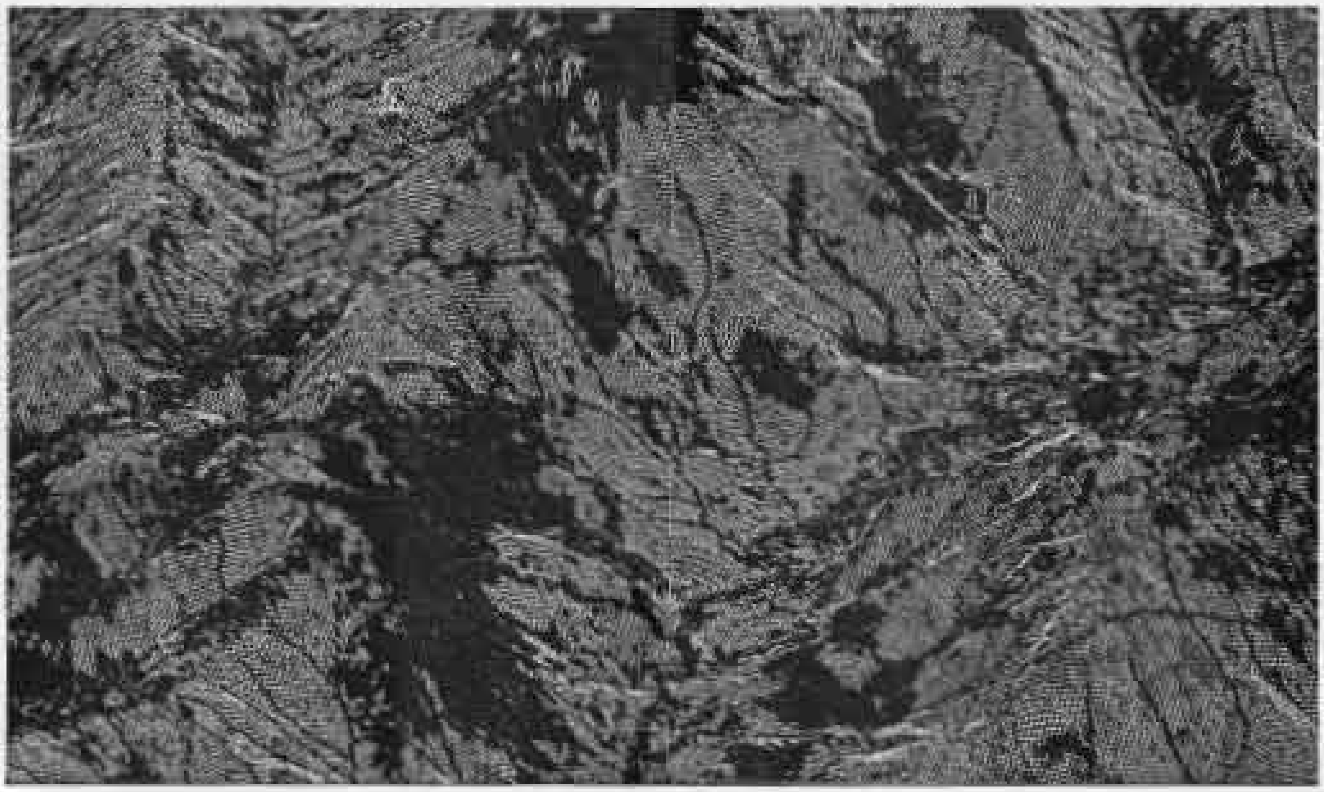


LANDSAT IMAGE MSS 4R261B 1984 FEB 03 LAMJUNG AREA, NEPAL

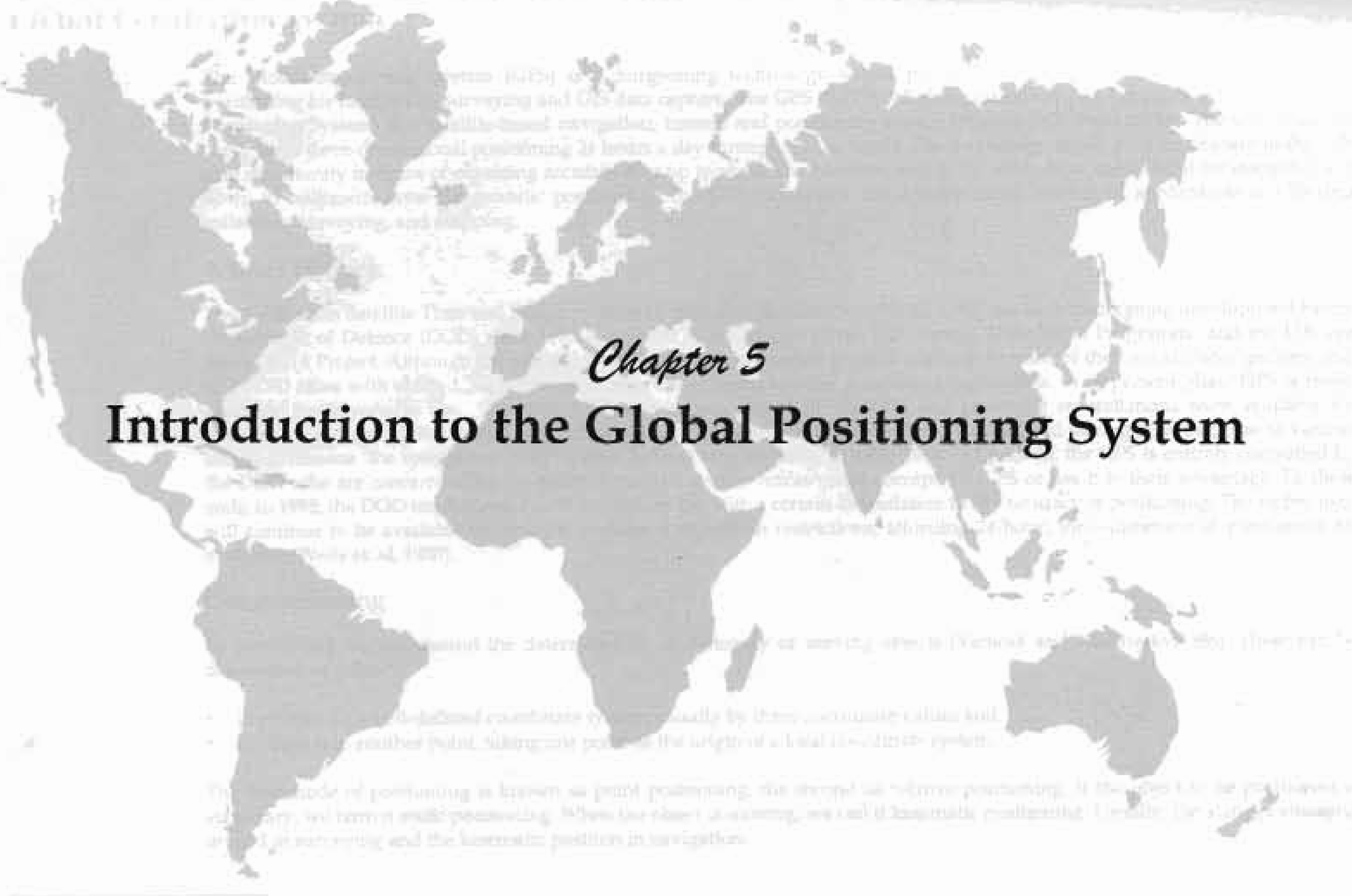
LANDCOVER BASED ON LANDSAT MSS DATA 1984 FEB 03 LAMJUNG AREA

LANDSAT IMAGE TM 4R362B 1994 MAY 13 LAMJUNG AREA, NEPAL

LANDCOVER BASED ON LANDSAT TM DATA 1994 MAY 13 LAMJUNG AREA



Overlay of Land Cover Classification over DTM with VDC Boundaries and Drainage System of Lamjung Area



Chapter 5

Introduction to the Global Positioning System

The Global Positioning System (GPS) is a burgeoning technology which provides unequalled accuracy and flexibility of positioning for navigation, surveying and GIS data capture. The GPS NAVSTAR (Navigation Satellite Timing and Ranging Global Positioning System) is a satellite-based navigation, timing, and positioning system (Harald, Jeff. Steve, 1993). The GPS provides continuous three-dimensional positioning 24 hours a day throughout the world. The technology seems to be beneficiary to the GPS user community in terms of obtaining accurate data up to about one hundred metres for navigation, metre-level for mapping, and down to millimetre level for geodetic positioning. The GPS technology has a tremendous amount of applications in GIS data collection, surveying, and mapping.

A Brief History

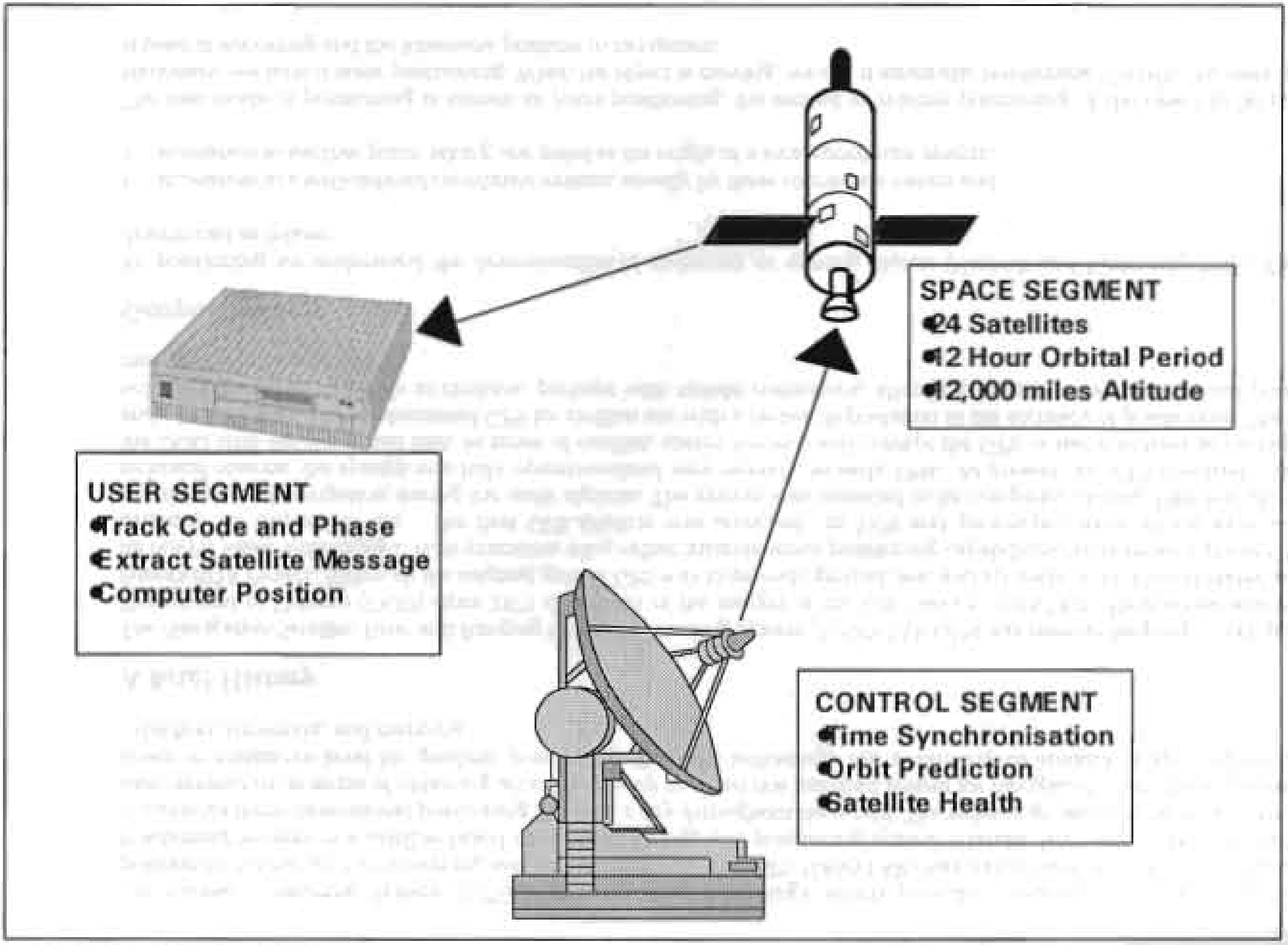
The Navigation Satellite Time and Ranging Global Positioning System (NAVSTAR GPS) has been undergoing development by the Department of Defence (DOD) since 1973 as a result of the merger of the U.S. Navy's TIMATION Programme and the U.S. Air Force's 621B Project. Although the original goal of GPS was to provide ground, sea, and air units of the United States' military and its NATO allies with unified, high-precision, all-weather instantaneous positioning capabilities, in its present phase GPS is freely available for anyone to use. The first GPS satellite was launched in 1978 and prototype constellations were available for positioning and navigation during the early eighties. The system was intended to be completed during 1988 but, due to various technical reasons the system was fully operationalised very recently, in early 1994. At present, the GPS is entirely controlled by the DOD who are concerned that, in times of conflict, enemy forces could corrupt the GPS or use it to their advantage. To these ends, in 1992, the DOD implemented GPS for civilian use with a certain degradation in the accuracy of positioning. The technology will continue to be available to civilians, perhaps with certain restrictions, affording 24-hour, three-dimensional positioning by mid-1993 (Wells et. al. 1988).

Geopositioning

By positioning we understand the determination of stationary or moving objects (Vanicek and Krakiwsky,1986). These can be determined as follow:

- in relation to a well-defined coordinate system, usually by three coordinate values and
- in relation to another point, taking one point as the origin of a local coordinate system.

The first mode of positioning is known as point positioning, the second as relative positioning. If the object to be positioned is stationary, we term it static positioning. When the object is moving, we call it kinematic positioning. Usually, the static positioning is used in surveying and the kinematic position in navigation.

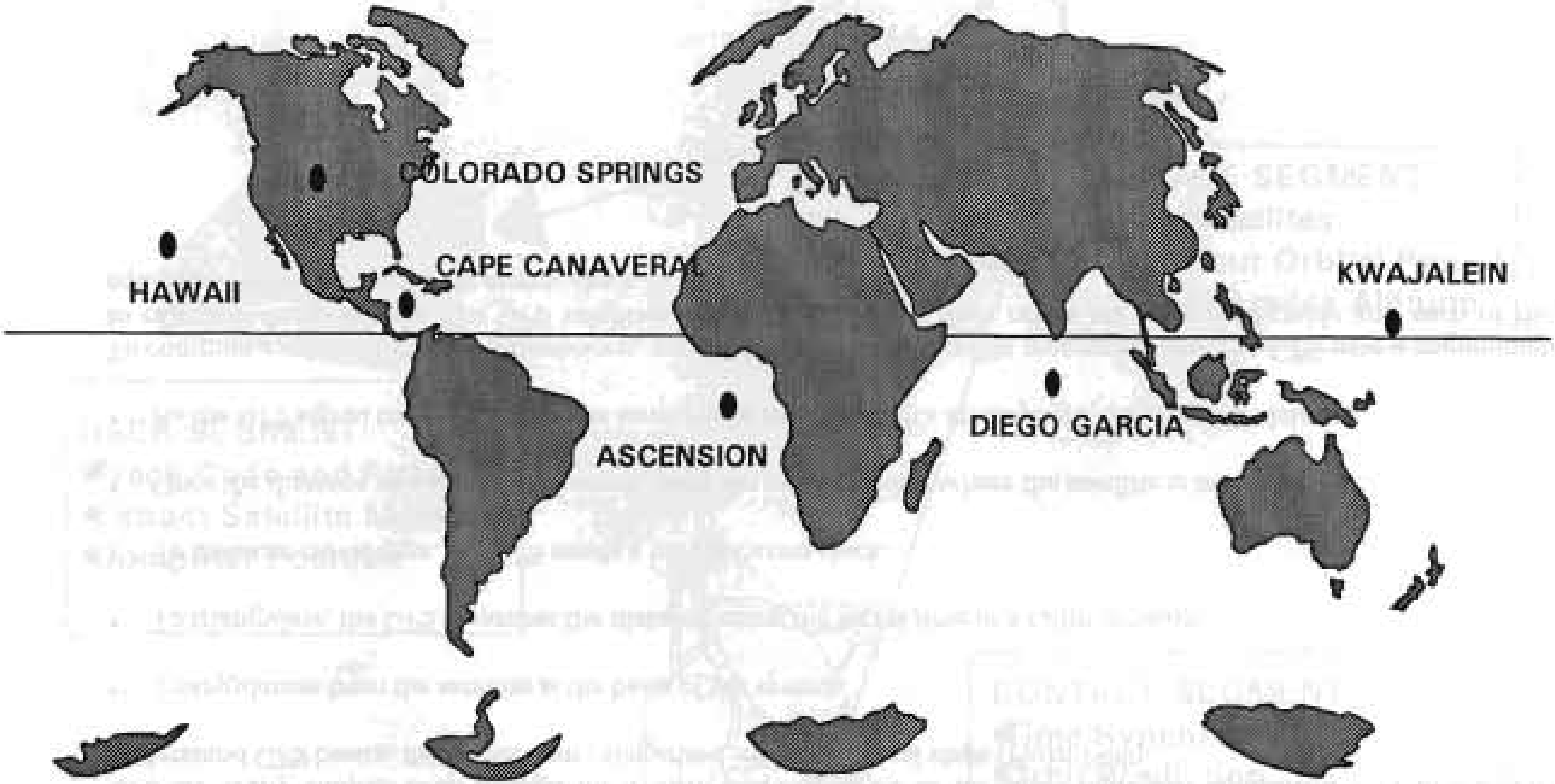

SPACE SEGMENT
•24 Satellites
•12 Hour Orbital Period
•12,000 miles Altitude
USER SEGMENT
•Track Code and Phase
•Extract Satellite Message
•Computer Position
CONTROL SEGMENT
•Time Synchronisation
•Orbit Prediction
•Satellite Health

GPS Basics

The GPS uses satellites and computers to compute positions anywhere on earth. The GPS is based on satellite ranging. That means the position on the earth is determined by measuring the distance from a group of satellites in space. The basic principles behind GPS are really simple, even though the system employs some of the most high-tech equipment ever developed. In order to understand GPS basics, the system can categorised into five logical steps (Hurn 1989).

- Triangulation from the satellite is the basis of the system.
- To triangulate, the GPS measures the distance using the travel time of a radio message.
- To measure travel time, the GPS needs a very accurate clock.
- Once the distance to a satellite is known, then we need to know where the satellite is in space.
- As the GPS signal travels through the ionosphere and the earth's atmosphere, the signal is delayed.

To compute a position in three dimensions, we need to have four satellite measurements. The GPS uses a trigonometric approach to calculate the positions, The GPS satellites are so high up that their orbits are very predictable and each of the satellites is equipped with a very accurate atomic clock.



GPS Control Segment Locations

Components of a GPS

The Global Positioning System is divided into three major components: the **control segment**, the **space segment**, and the **user segment**. All three of these segments are required to perform positional determination.

Control Segment

The Control Segment consists of five monitoring stations (Colorado Springs, Ascension Island, Diego Garcia, Hawaii, and Kwajalein Island). Three of the stations (Ascension, Diego Garcia, and Kwajalein) serve as uplink installations, capable of transmitting data to the satellites, including new ephemerides (satellite positions as a function of time), clock corrections, and other broadcast message data, while Colorado Springs serves as the master control station. The Control Segment is the sole responsibility of the DOD who undertakes construction, launching, maintenance, and virtually constant performance monitoring of all GPS satellites.

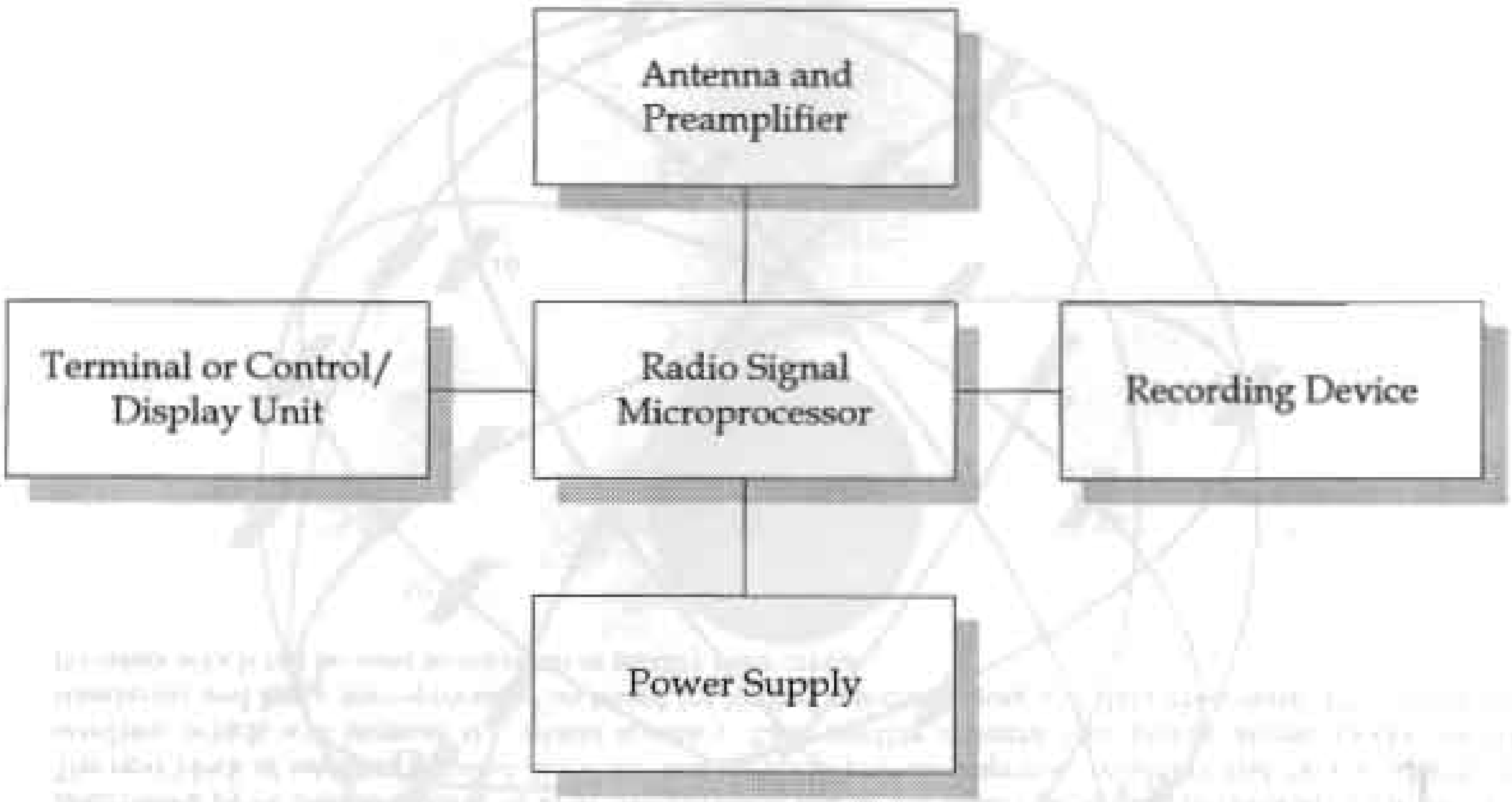
The DOD monitoring stations track all GPS signals for use in controlling the satellites and predicting their orbits. Meteorological data also are collected at the monitoring stations, permitting the most accurate evaluation of tropospheric delays of GPS signals. Satellite tracking data from the monitoring stations are transmitted to the master control stations, permitting the most accurate evaluation of tropospheric delays of GPS signals. Satellite tracking data from the monitoring stations are transmitted to the master control station for processing. This processing involves the computation of satellite ephemerides and satellite clock corrections. The master station controls orbital corrections, when any satellite strays too far from its assigned position, and necessary repositioning to compensate for unhealthy (not fully functioning) satellites.

Source: *Canadian GPS Association*

Space Segment

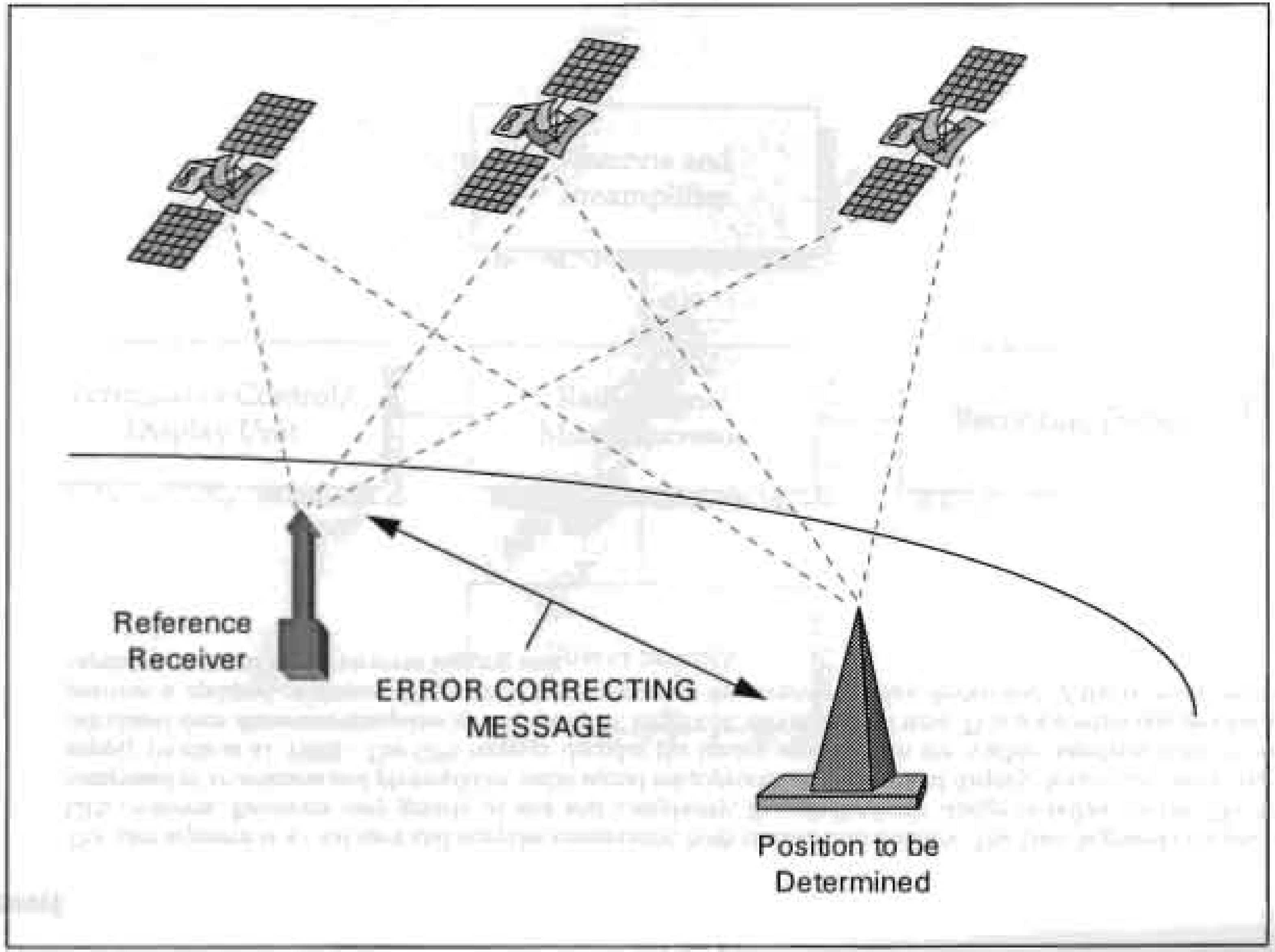
Space Segment

The Space Segment consists of the constellation of NAVSTAR earth orbiting satellites. The current Defence Department plan calls for a full constellation of 24 Block II satellites (21 operational and 3 in-orbit spares). The satellites are arrayed in 6 orbital planes, inclined 55 degrees to the equator. They orbit at altitudes of about 12,000 miles each, with orbital periods of 12 sidereal hours (i.e., determined by or from the stars), or approximately one half of the earth's periods, approximately 12 hours of 3-D position fixes. The next block of satellites is called Block IIR, and they will provide improved reliability and have a capacity of ranging between satellites, which will increase the orbital accuracy. Each satellite contains four precise atomic clocks (Rubidium and Cesium standards) and has a microprocessor on board for limited self-monitoring and data processing. The satellites are equipped with thrusters which can be used to maintain or modify their orbits.


Antenna and Preamplifier
Terminal or Control/ Display Unit
Radio Signal Microprocessor
Recording Device
Power Supply

User Segment

The user segment is a total user and supplier community, both civilian and military. The User Segment consists of all earth-based GPS receivers. Receivers vary greatly in size and complexity, though the basic design is rather simple. The typical receiver is composed of an antenna and preamplifier, radio signal microprocessor, control and display device, data recording unit, and power supply (Wells et al. 1988) . The GPS receiver decodes the timing signals from the 'visible' satellites (four or more) and, having calculated their distances, computes its own latitude, longitude, elevation, and time. This is a continuous process and generally the position is updated on a second-by-second basis, output to the receiver display device and, if the receiver provides data capture capabilities, stored by the receiver logging unit.


Reference
Receiver
ERROR CORRECTING
MESSAGE
Position to be
Determined

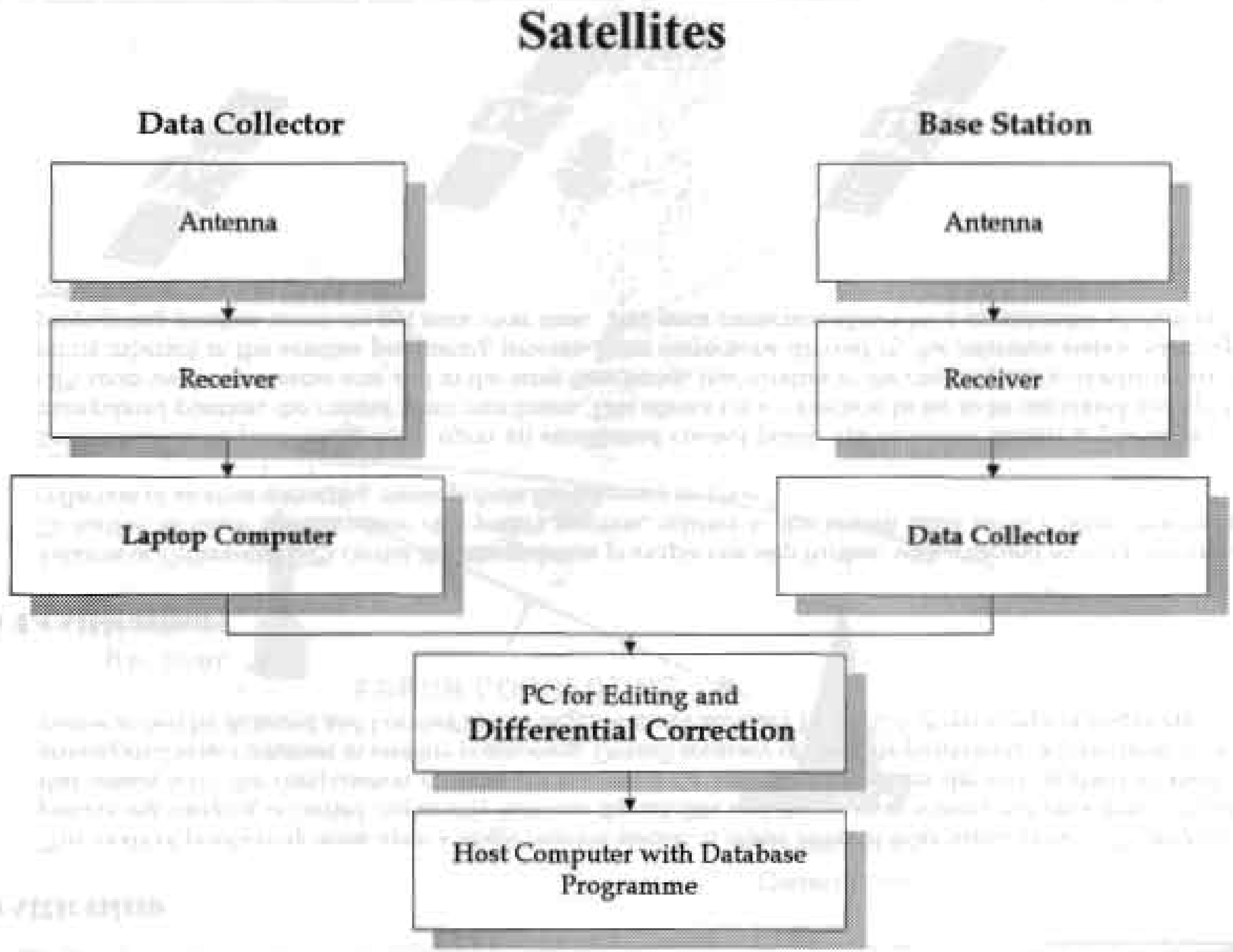
Absolute Positioning

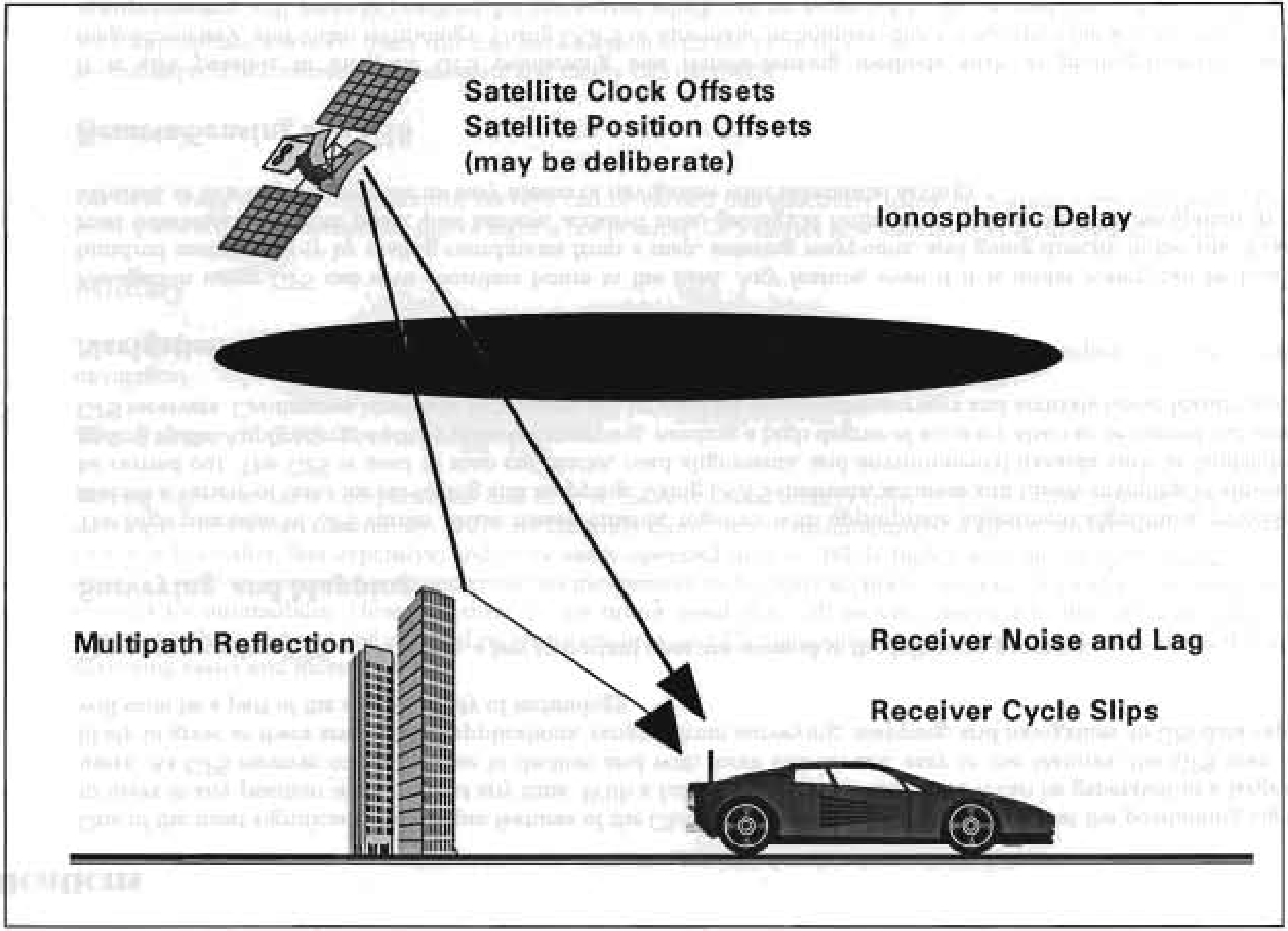
This mode of positioning relies upon a single receiver station. It is also referred to as 'stand-alone' GPS, because, unlike differential positioning, ranging is carried out strictly between the satellite and the receiver station, not on a ground-based reference station that assists with the computation of error corrections. As a result, the positions derived in absolute mode are subject to the unmitigated errors inherent in satellite positioning. Overall accuracy of absolute positioning is considered to be no greater than 50 metres at best by Ackroyd and Lorimer and to be ± 100-metre accuracy by the U.S. Army Corps of Engineers.

Differential Positioning

Relative or Differential GPS carries the triangulation principle one step further, with a second receiver at a known reference point. To further facilitate determination of a point's position, relative to the known earth surface point, this configuration demands collection of an error correcting message from the reference receiver.

Differential-mode positioning relies upon an established control point. The reference station is placed on the control point; a triangulated position, the control point coordinate. This allows for a correction factor to be calculated and applied to other roving GPS units used in the same area and in the same time series. Inaccuracies in the control point's coordinate are directly additive to errors inherent in the satellite positioning process. Error corrections derived by the reference station vary rapidly as the factors propagating position errors are not static over time. This error correction allows for a considerable amount of error to be negated, potentially as much as 90 per cent.


Satellites
Data Collector
Base Station
Antenna
Receiver
Laptop Computer
Antenna
Receiver
Data Collector
PC for Editing and
Differential Correction
Host Computer with Database
Programme


Satellite Clock Offsets
Satellite Position Offsets
(may be deliberate)
Ionospheric Delay
Multipath Reflection
Receiver Noise and Lag
Receiver Cycle Slips

GPS Applications

One of the most significant and unique features of the Global Positioning System is the fact that the positioning signal is available to users in any position worldwide at any time. With a fully operational GPS system, it can be generated to a large community of users. As GPS receiver costs continue to decline, and with more add-on and easy to use features, the GPS user community is likely to grow as there are multiple applications, ranging from surveying, mapping, and navigation to GIS data capture. The GPS will soon be a part of the overall utility of technology.

There are countless GPS applications, a few important ones are covered in the following passages.

Surveying and Mapping

The high precision of GPS carrier phase measurements, together with appropriate adjustment algorithms, provide an adequate tool for a variety of tasks for surveying and mapping. Using DGPS methods, accurate and timely mapping of almost anything can be carried out. The GPS is used to map cut blocks, road alignments, and environmental hazards such as landslides, forest fires, and oil spills. Applications, such as cadastral mapping, needing a high degree of accuracy also can be carried out using high-grade GPS receivers. Continuous kinematic techniques can be used for topographic surveys and accurate linear feature mapping.

Navigation

Navigation using GPS can save countless hours in the field. Any feature, even if it is under water, can be located up to one hundred metres simply by scaling coordinates from a map, entering waypoints, and going directly to the site. Examples include road intersections, corner posts, plot canters, accident sites, geological formations, and so on. GPS navigation in helicopters, in vehicles, or in a ship can provide an easy means of navigation with substantial savings.

Remote Sensing and GIS

It is also possible to integrate GPS positioning into remote-sensing methods such as photogrammetry, aerial scanning, magnetometery, and video technology. Using DGPS or kinematic techniques, depending upon the accuracy required, real time or post-processing will provide positions for the sensor which can be projected to the ground, instead of having ground control projected to an image. GPS are becoming very effective tools for GIS data capture. The GIS user community benefits from the use of GPS for locational cata capture in various GIS applications. The GPS can easily be linked to a laptop computer in the field, and, with appropriate software, users can also have all their data on a common base with very little distortion. Thus GPS can help in several aspects of construction of accurate and timely GIS databases.

Geodesy

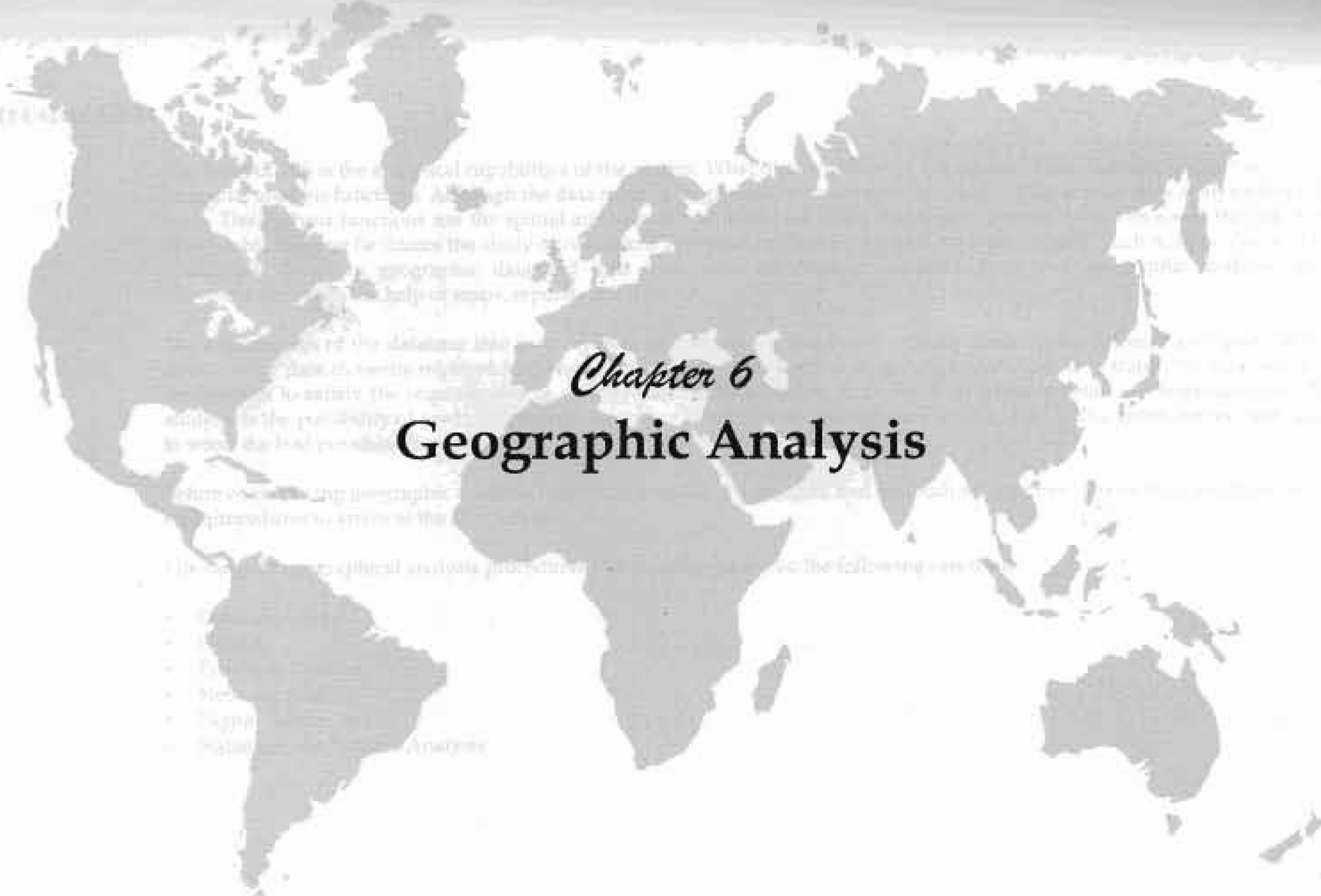
Geodetic mapping and other control surveys can be carried out effectively using high-grade GPS equipment. Especially when helicopters are used or when the line of sight is not possible, GPS can set new standards of accuracy and productivity.

Military

The GPS was primarily developed for real time military positioning. Military applications include airborne, marine, and land navigation.

The Future of GPS Technology

Barring significant new complications due to S/A (Selective Availability) from DOD, the GPS industry is likely to continue to develop in the civilian community. There are currently more than 50 manufacturers of GPS receivers, with the trend continuing to be towards smaller, less expensive, and more easily-operated devices. While highly accurate, portable (hand-held) receivers are already available, current speculation envisions inexpensive and equally accurate 'wristwatch locators' and navigational guidance systems for automobiles. However, there is one future trend that will be very relevant to the GIS user community, namely, community base stations and regional receiver networks, as GPS management and technological innovations that will make GPS surveying easier and more accurate.



Chapter 6

Geographic Analysis

Introduction

The heart of GIS is the analytical capabilities of the system. What distinguishes the GIS system from other information systems are its spatial analysis functions. Although the data input is, in general, the most time consuming part, it is for data analysis that GIS is used. The analysis functions use the spatial and non-spatial attributes in the database to answer questions about the real world. Geographic analysis facilitates the study of real-world processes by developing and applying models. Such models illuminate the underlying trends in geographic data and thus make new information available. Results of geographic analysis can be communicated with the help of maps, reports, or both.

The organisation of the database into map layers is not simply for reasons of organisational clarity, rather it is to provide rapid access to the data elements required for geographic analysis. The objective of geographic analysis is to transform data into useful information to satisfy the requirements or objectives of decision-makers at all levels in terms of detail. An important use of the analysis is the possibility of predicting events in another location or at another point in time. This ability gives one the opportunity to select the best possible alternative.

Before commencing geographic analysis, one needs to assess the problem and establish an objective. The analysis requires step-by-step procedures to arrive at the conclusions.

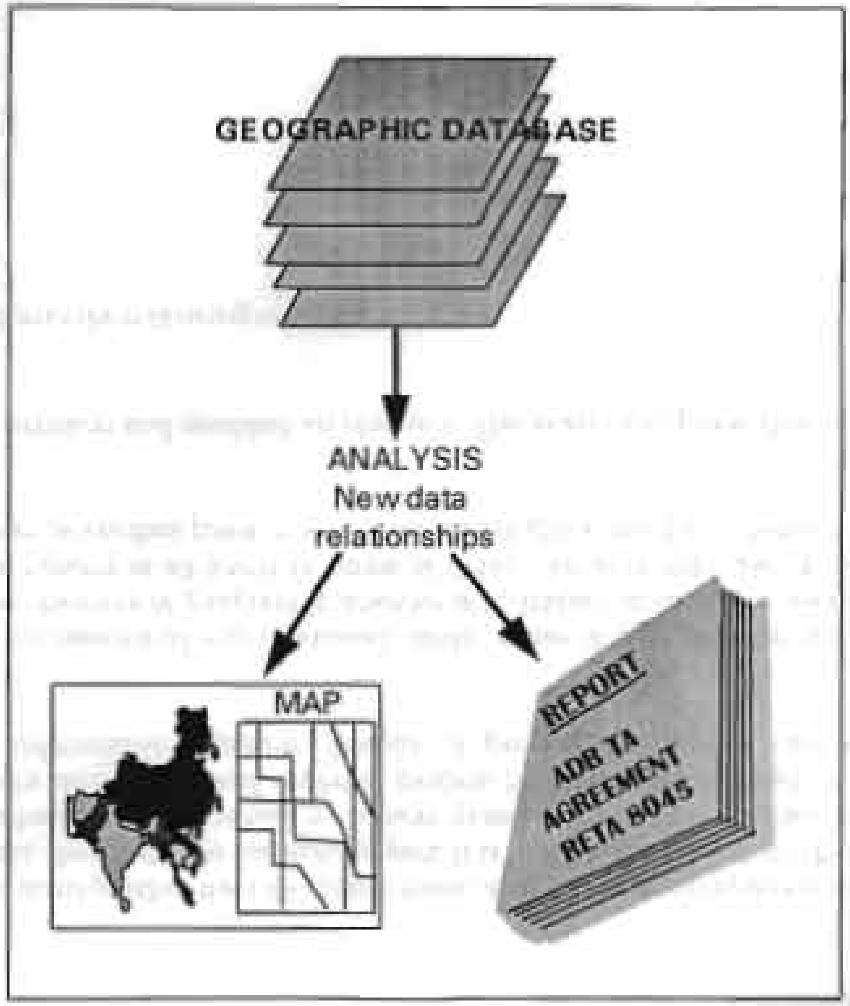
The range of geographical analysis procedures can be subdivided into the following categories.

- Database Query
- Overlay
- Proximity Analysis
- Network Analysis
- Digital Terrain Model
- Statistical and Tabular Analysis

Spatial Analysis

It helps you

- identify trends in the data,
- create new relationships from the data,
- view complex relationships between data sets, and
- make better decisions.



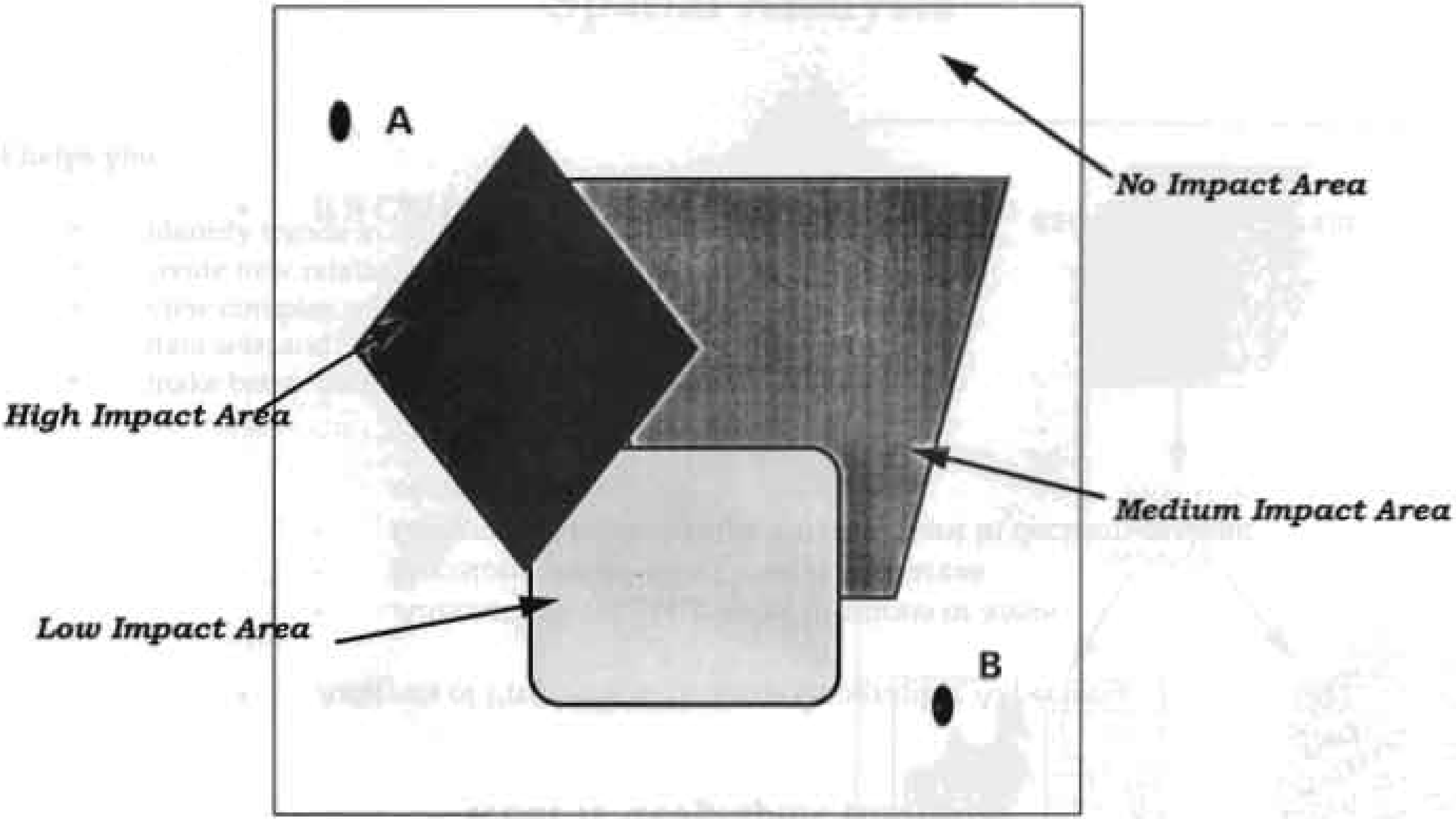
What Is Geographic Analysis?

- Analysis of Problems with Some Geographic Aspects

  - Alternatives are geographic locations or areas
  - Decisions would affect locations or areas
  - Geographic relationships are important in decision-making or modelling

  Nearest Neighbour
  Network Distances
  Planar Distances
  Boundary Conditions

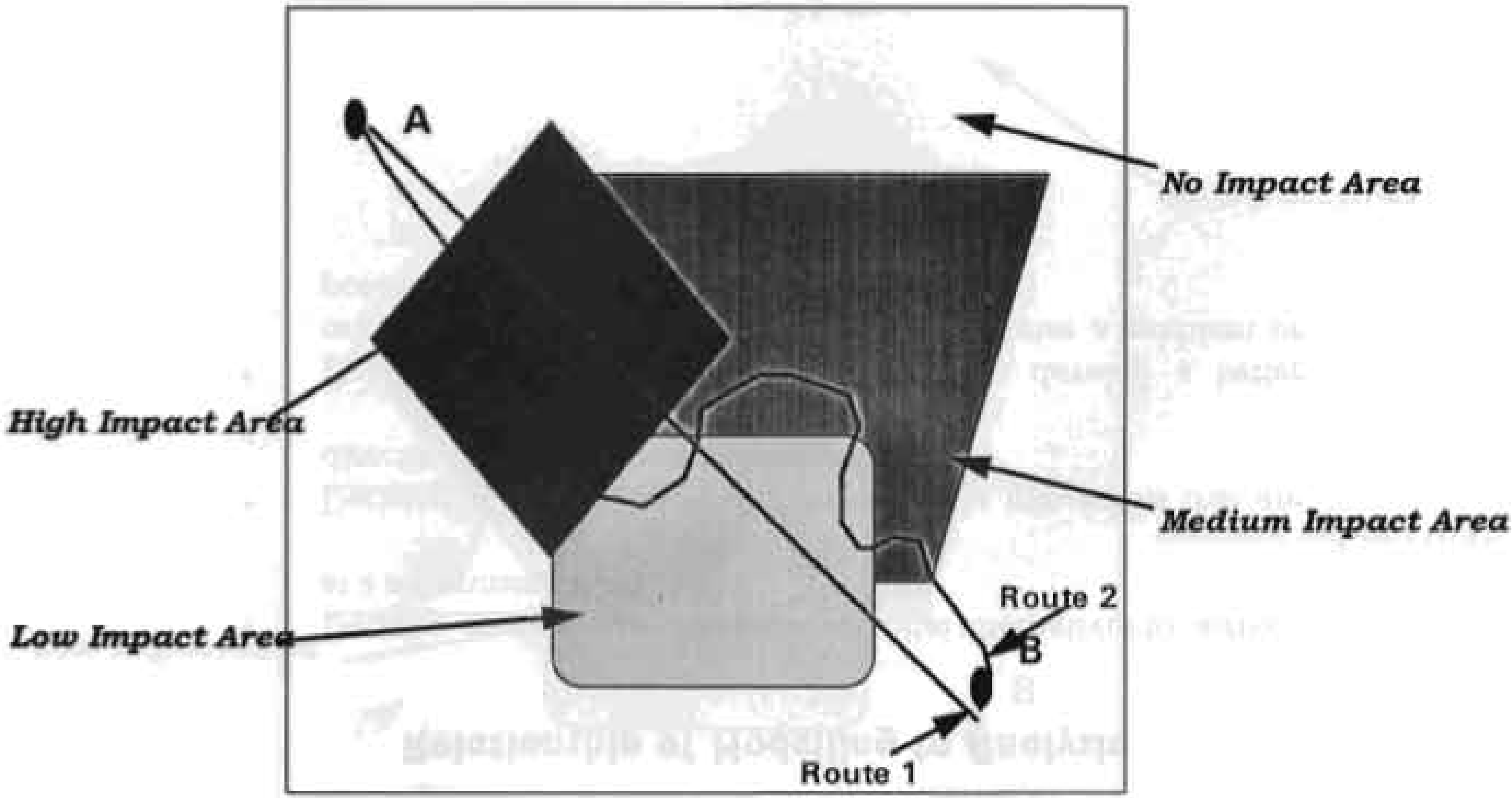
- If It Can Be Mapped, It's Geography



Where should we build a road from point A to Point B?
How do we minimise the impacts of building this road?

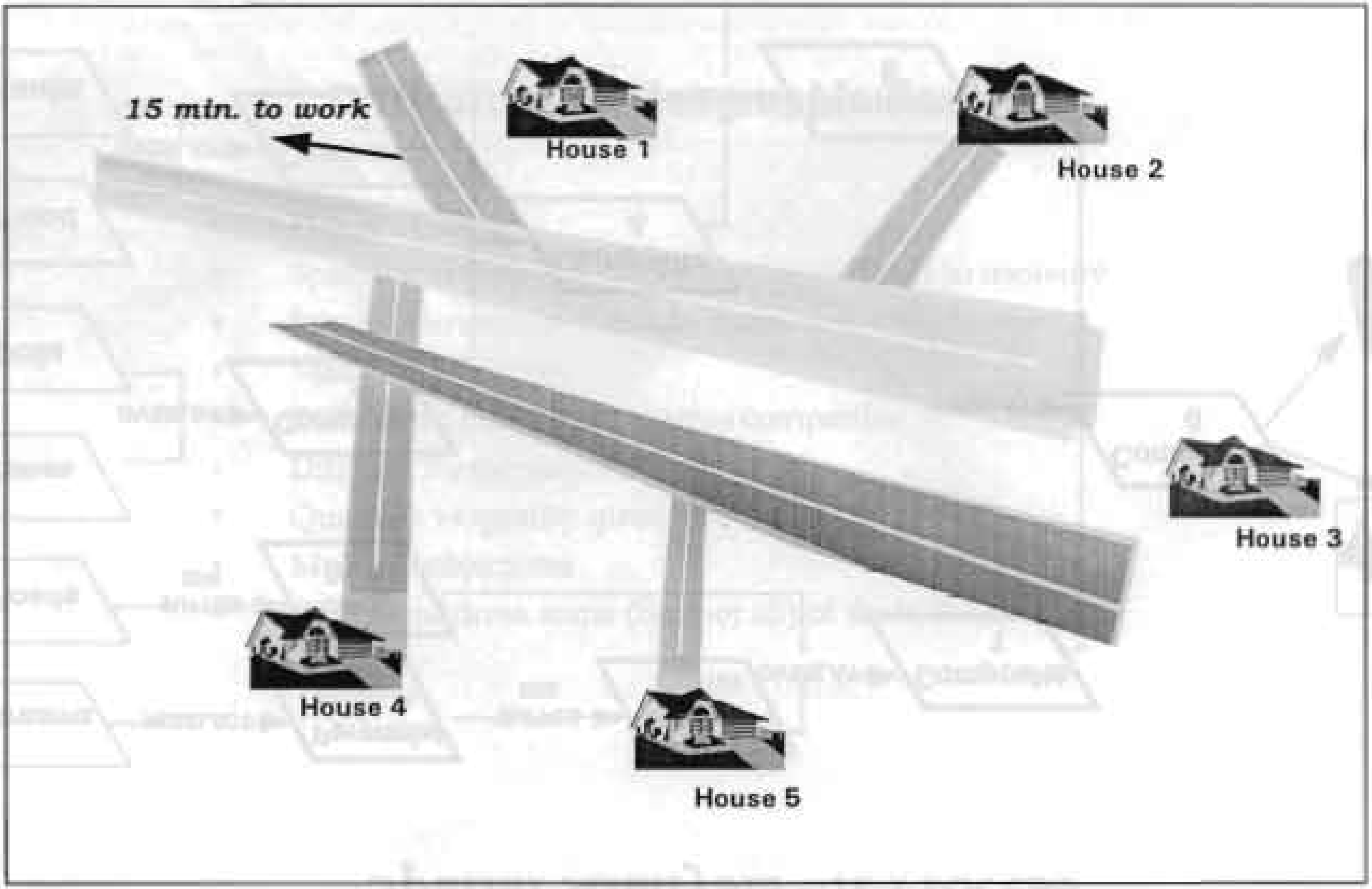
Relationship of Modelling to Analysis

- Decision models search through potential alternatives to arrive at a recommendation
- Decision support models process raw data into forms that are directly relevant to decision-making
- Data characterisation models are used to develop a better understanding of a system to help characterise a problem or potential solutions

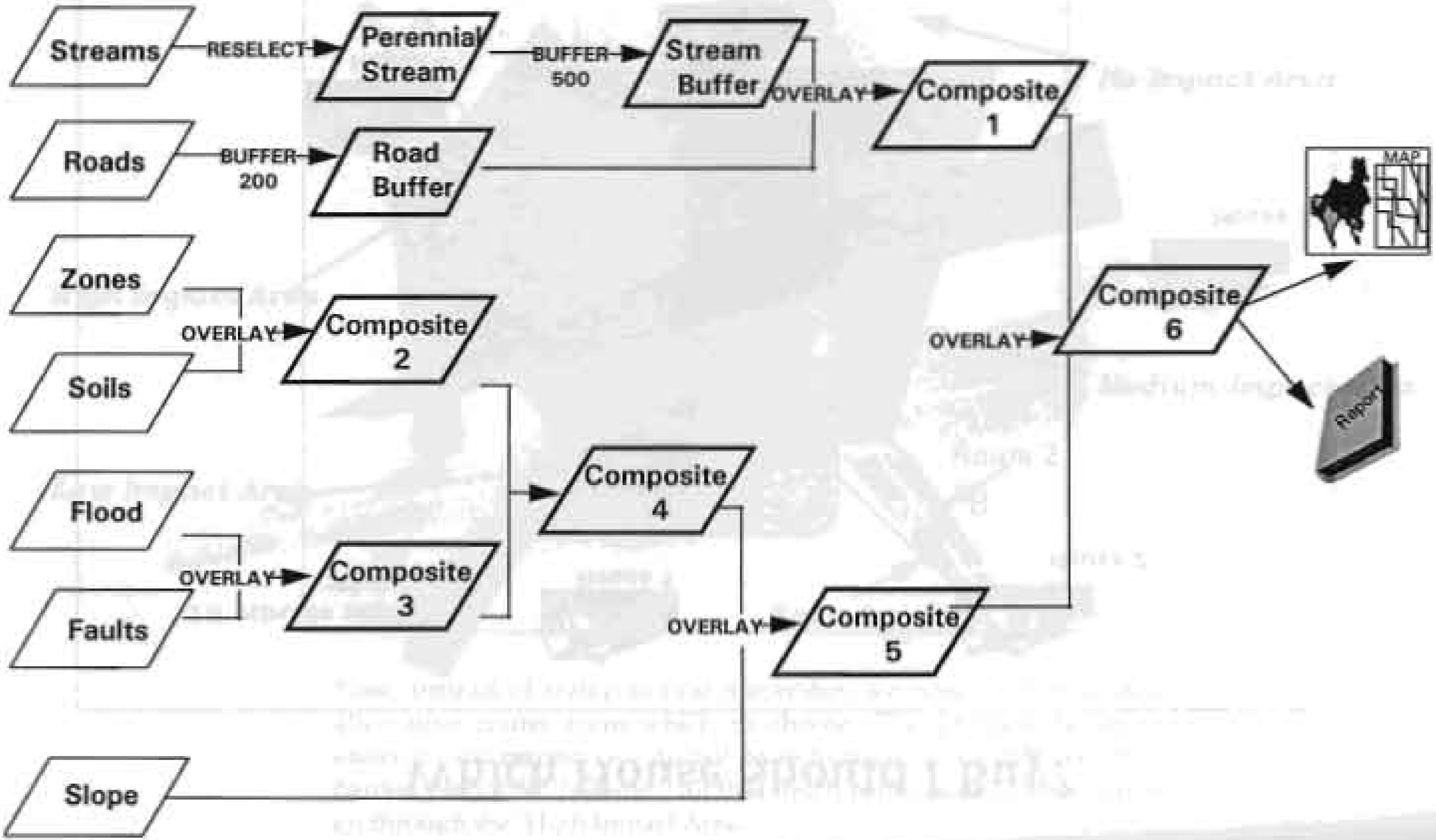


Now, instead of trying to find a corridor, we now have only two alternative routes from which to choose. The problem becomes easier in one respect (we do not have to think of alternatives), but harder in another. Is route 2 all that much better because it does not go through the 'High Impact Area'?

Which House Should I Buy?



Spatial Analysis - A Process



Difficulties of Geographic Analysis

- Plenty of data
- Spatial relationships important but difficult to measure
- Inherent uncertainty due to scale
- Many data sources
- Difficult to make data sources compatible
- Difficult mathematics
- Quantity vs quality questions
- Multiple objectives
- GIS can address some (but not all) of these difficulties

Database query

- Query by Attribute
- Query by Geometry
    - Query by Point
    - Query by Rectangle
    - Query by Circle
    - Query by Line
    - Query by Polygon

Database Query

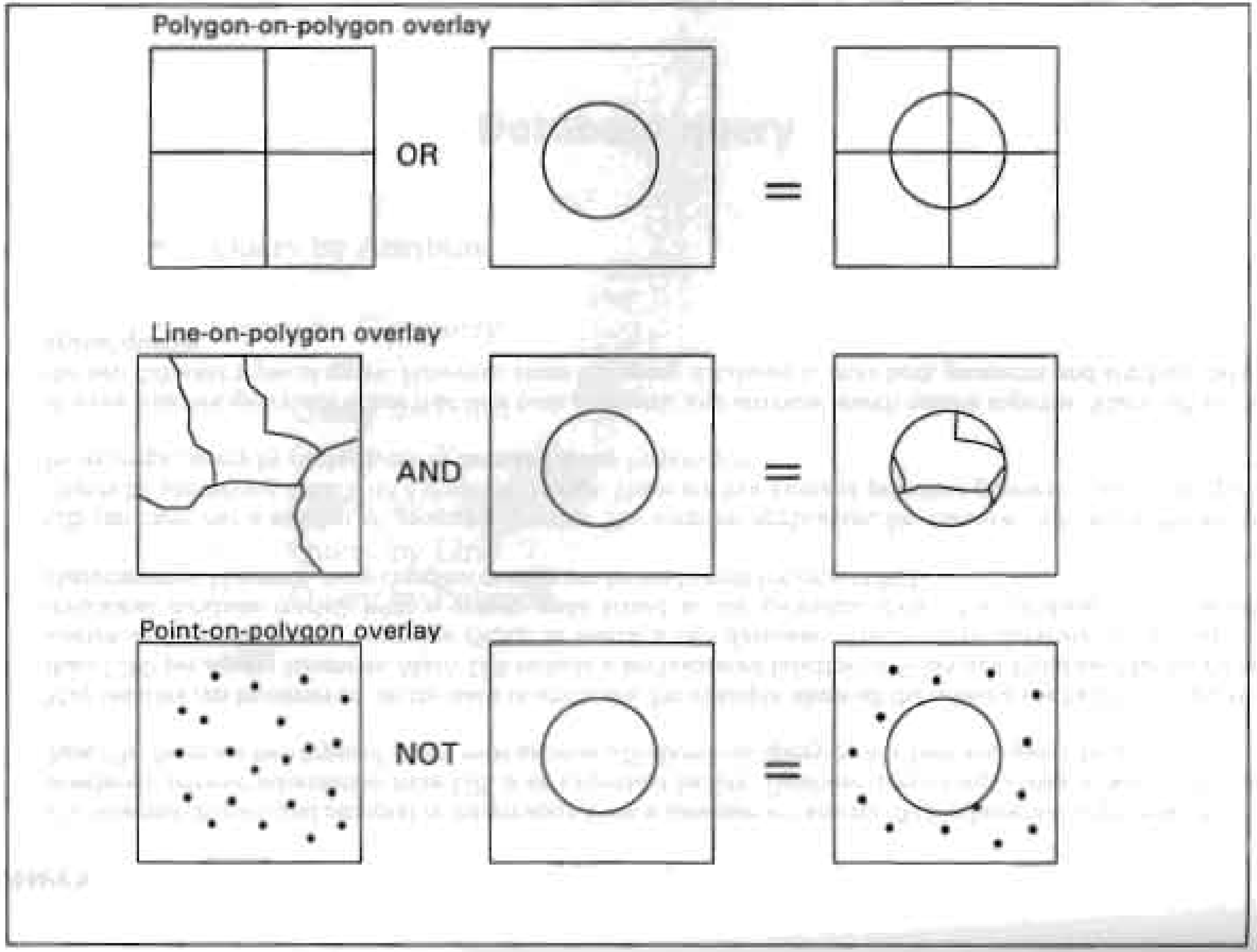
The selective display and retrieval of information from a database are among the fundamental requirements of GIS. The ability to selectively retrieve information from GIS is an important facility. Database query simply asks to see already stored information. Basically, there are two types of query most general GIS allow: viz, query by attribute and query by geometry.

Map features can be retrieved on the basis of attributes. For example, show all the urban areas having a population density greater than 1,000 per square kilometre. Many GIS include a sophisticated function of Relational Database Management Sytem (RDBMS), known as Standard Query Language (SQL), to search a GIS database. The attribute database, in general, is stored in a table (relational database model) with a unique code linked to the geometric data. This database can be searched with specific characteristics. However, more complex queries can be made with the help of SQL.

GIS can carry out a number of geometric queries. The simplest application, for example, is to show the attributes of displayed objects by identifying them with a graphical cursor. There are five forms of primitive geometric query: viz, query by point, query by rectangle, query by circle, query by line, and query by polygon.

A more complex query still is one that uses both geometric and attribute search criteria together. Many GIS force the separation of the two different types of query. However, some GIS using databases to store both geometric and attribute data allow true hybrid spatial queries.

Polygon-on-Polygon Overlay



Overlay Operations

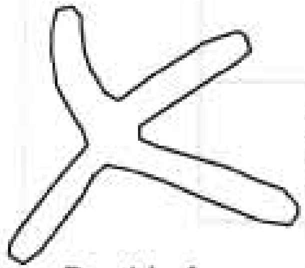
The hallmark of GIS is overlay operations. Using these operations, new spatula elements are created by the overlaying of maps. There are basically two different types of overlay operation depending upon data structures: raster and vector overlay. The raster overlay is a relatively straightforward operation and often many datasets can be combined and displayed at once. The vector overlay, however, is far more difficult and complex and involves more processing.

Logical Operators

The concept of map logic can be applied during overlay. The logical operators are Boolean functions. There are basically four types of Boolean operator: viz., OR, AND, NOT, and XOR.

With the use of logical, or Boolean, operators spatial elements/or attributes are selected that fulfill a certain condition, depending on two or more spatial elements or attributes.

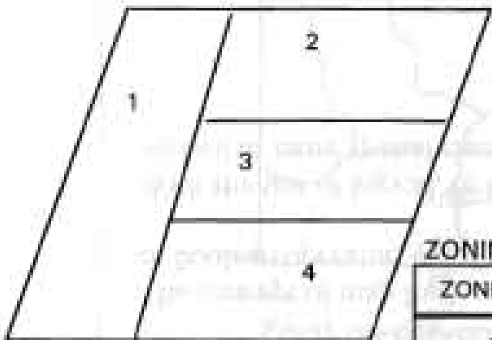
What's the Difference Between a Topologic Overlay and a Graphic Overplot?



Road.buf

ROADBUF.PAT

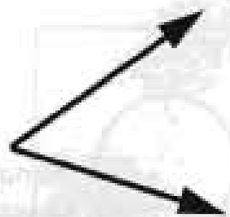
ROADBUF.ID	INSIDE
0	1
0	100



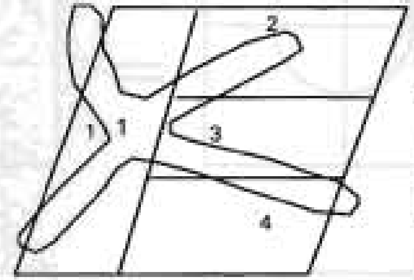
Zoning

ZONING.PAT

ZONING-ID	ZONE
0	-
1	IND
2	RES
3	COM
4	RES



GRAPHIC OVERPLOT



ROADBUF & ZONING
(features remain separate)

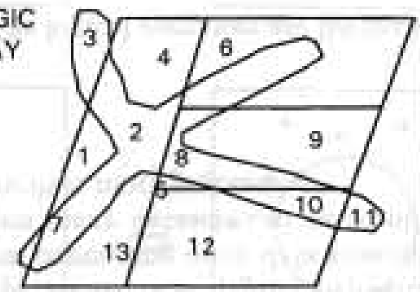
ROADBUF.PAT

ROADBUF.ID	INSIDE
0	1
0	100

ZONING.PAT

ZONING-ID	ZONE
0	-
1	IND
2	RES
3	COM
4	RES

TOPOLOGIC OVERLAY



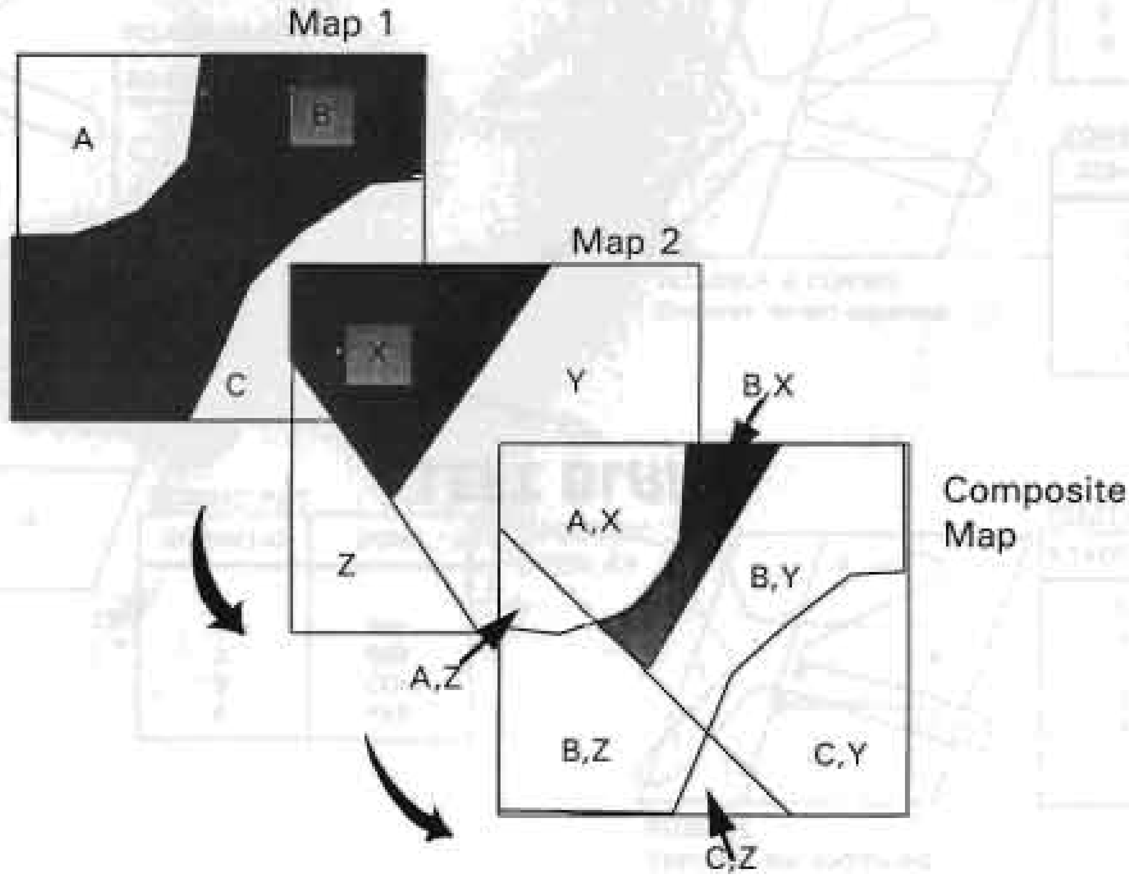
RDZONE
(features are combined)

RDZONE.PAT

ROADBUF.ID	ZONE	INSIDE
0	-	1
1	IND	1
2	RES	100
3	COM	100
4	RES	1
.	.	.
.	.	.

LEFT BLANK

Vector Overlay Example

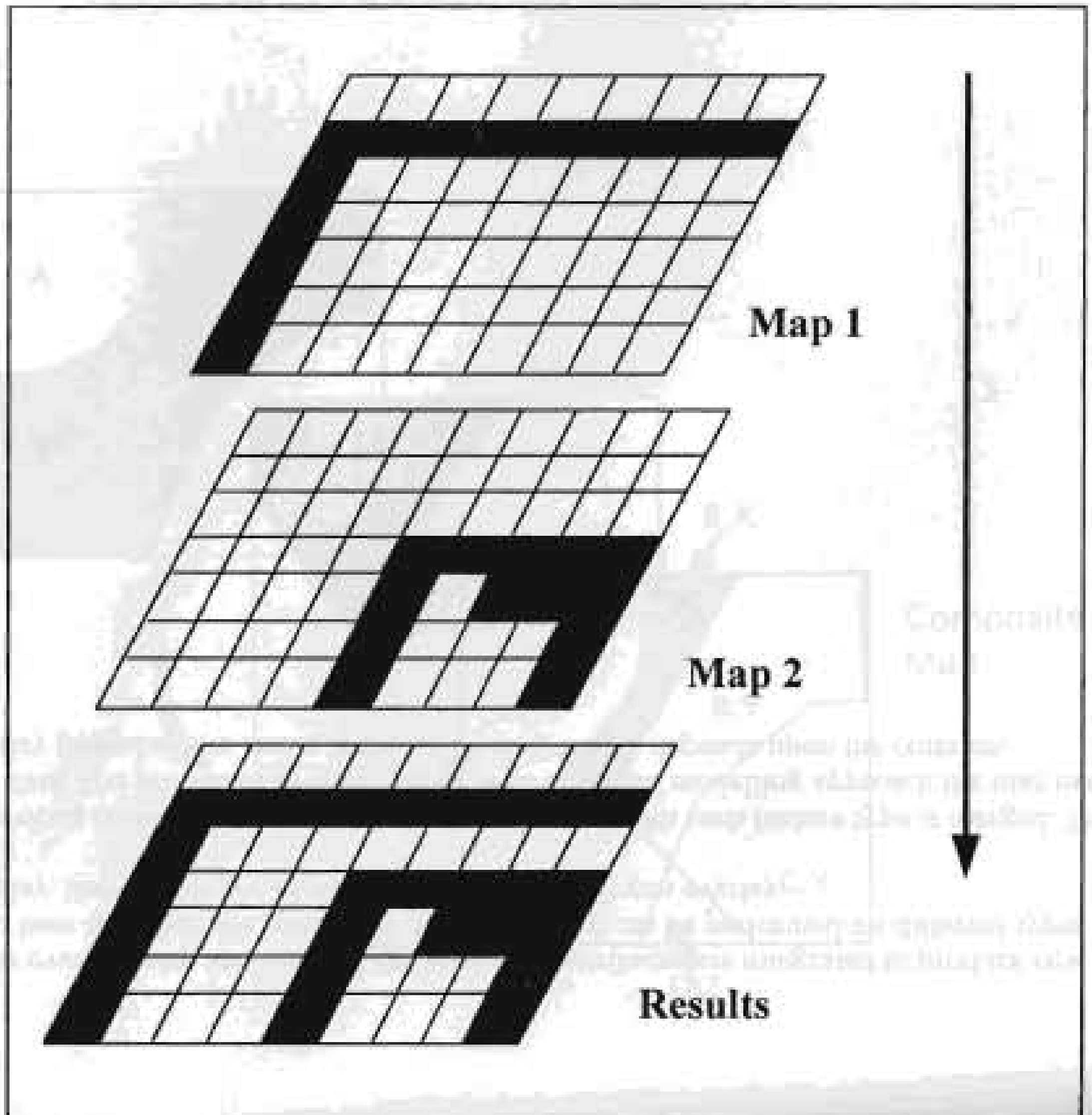


Vector Overlay

During vector overlay, map features and the associated attributes are integrated to produce new composite maps. Logical rules can be applied to how the maps are combined. Vector overlay can be performed on different types of map features: viz., polygon-on-polygon overlay, line-in-polygon overlay, and point-on-polygon overlay.

During the process of overlay, the attribute data associated with each feature type is merged. The resulting table will contain both the attribute data. The process of overlay will depend upon the modelling approach the user needs. One might need to carry out a series of overlay procedures to arrive at the conclusion, which depends upon the criterion.

Raster Overlay



Raster Overlay

In raster overlay, the pixel or grid cell values in each map are combined using arithmetic and Boolean operators to produce a new value in the composite map. The maps can be treated as arithmetical variables and perform complex algebraic functions. The method is often described as map algebra. The raster GIS provides the ability to perform map layers mathematically. This is particularly important for the modelling in which various maps are combined using various mathematical functions. Conditional operators are the basic mathematical functions that are supported in GIS.

Conditional operators

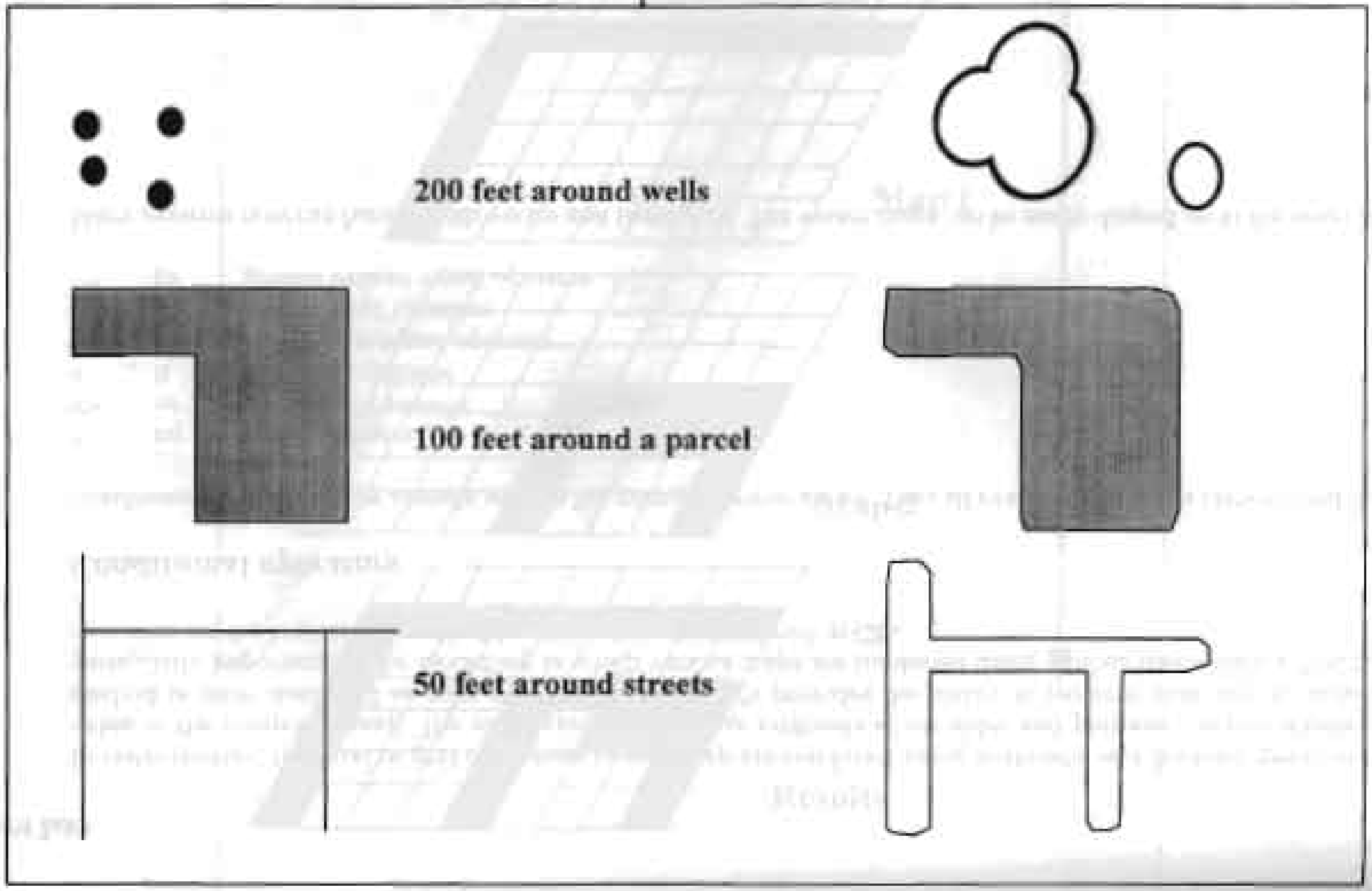
Conditional operators were already used in the examples given above. They all evaluate whether a certain condition has been met.

=	eq	'equal' operator
<>	ne	'non-equal' operator
<	lt	'less than' operator
<=	le	'less than or equal' operator
>	gt	'greater than' operator
>=	ge	'greater than or equal' operator

Many systems now can handle both vector and raster data. The vector maps can be easily draped on to the raster maps.

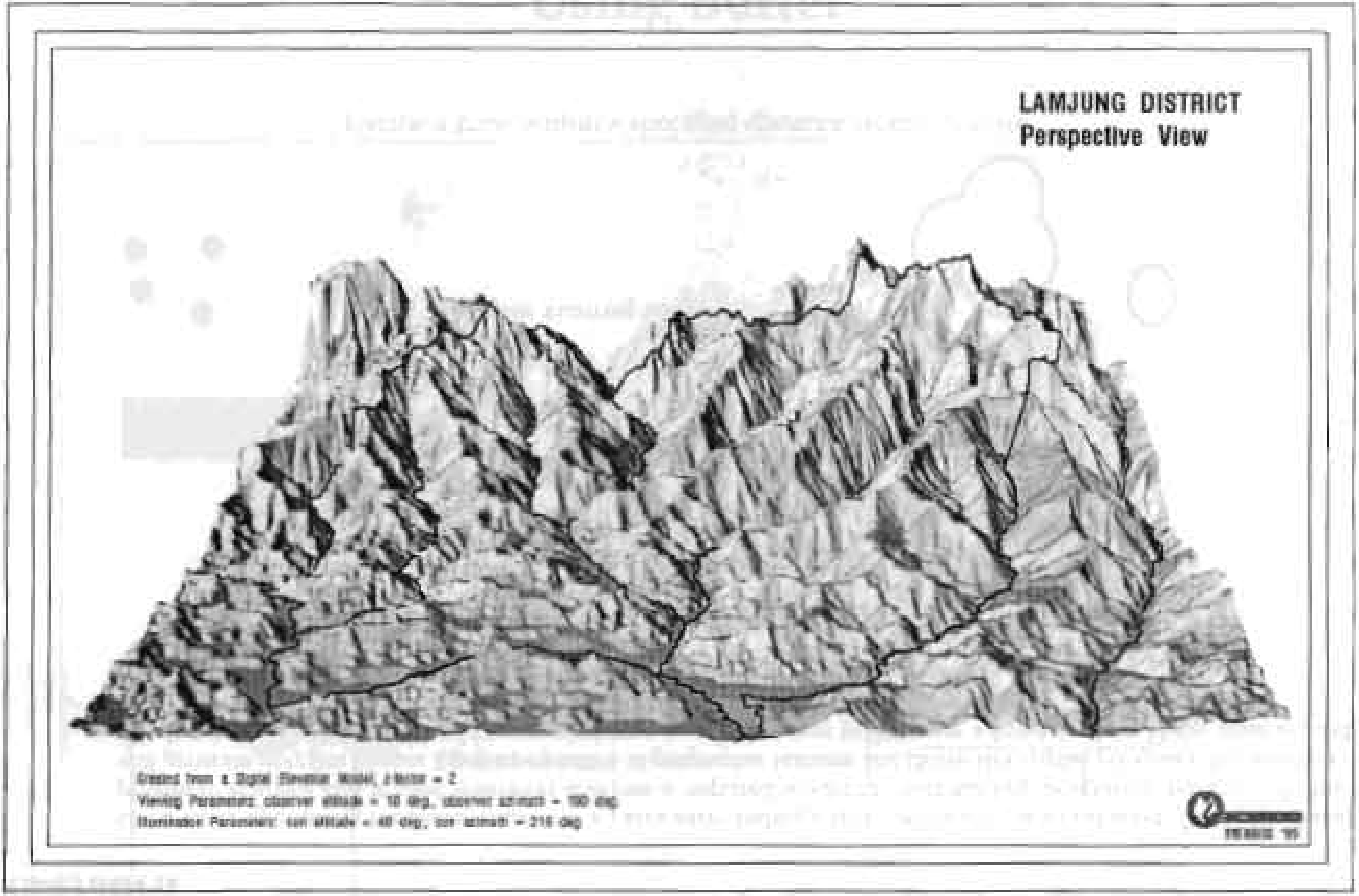
Using Buffer

Define a zone within a specified distance from a feature



Buffer Operation

Using these operations, the characteristics of an area surrounding a specified location are evaluated. This kind of analysis is called proximity analysis and is used whenever analysis is required to identify surrounding geographic features. The buffer operation will generate polygon feature types irrespective of geographic features and delineates spatial proximity. For example, what are the effects on urban areas if the road is expanded by a hundred metres to delineate a five-kilometre buffer zone around the national park to protect it from grazing?


LAMJUNG DISTRICT
Perspective View

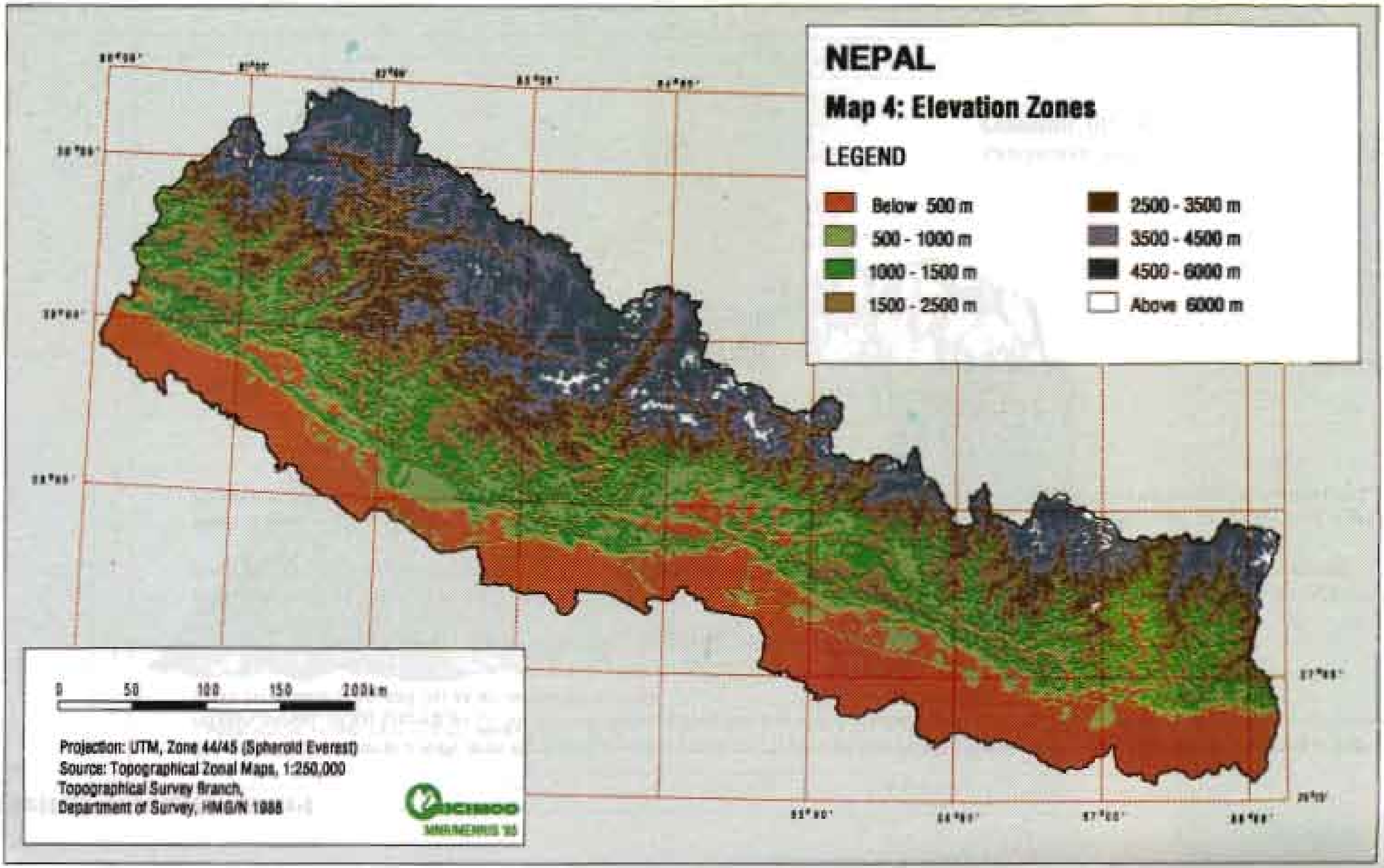
Digital Terrain Model

The object of terrain analysis is to represent a surface and its properties accurately. This is normally achieved by creating a digital terrain model, often known as DTM, formed by sampling the surface. A digital terrain model can be viewed in two different ways: (i) as an isoline map and (ii) as an isometric model.

Isolines join points of equal value on a surface. The shading defines bands, including all heights, between the isolines.

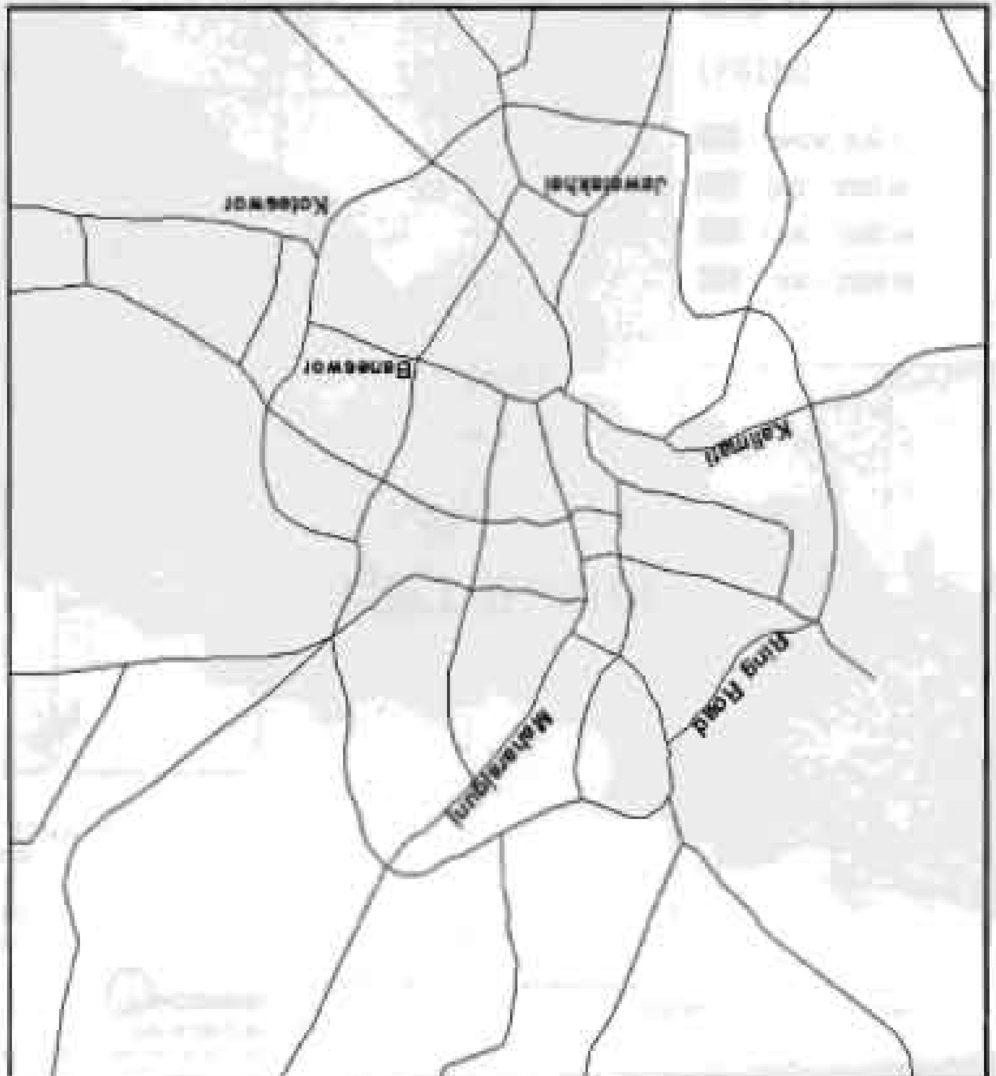
Isometric models can be shown in three dimensional models. These models show the terrain in perspective so that the apparent height is proportional to the value of the point. Visualisation techniques are used to project the model from the given eyepoint.

Basic terrain analyses operations can be used to create visualisations of surfaces when the data already exist in the form of a grid. However, when the data are scattered and in non-regular spatial format, more sophisticated techniques of interpolation are used.


NEPAL
Map 4: Elevation Zones
LEGEND
Below 500 m
500 - 1000 m
1000 - 1500 m
1500 - 2500 m
2500 - 3500 m
3500 - 4500 m
4500 - 6000 m
Above 6000 m
0 50 100 150 200km
Projection: UTM, Zone 44/45 (Spheroid Everest)
Source: Topographical Zonal Maps, 1:250,000
Topographical Survey Branch,
Department of Survey, HMG/N 1988

LEFT BLANK

Network Analysis



Network Analysis

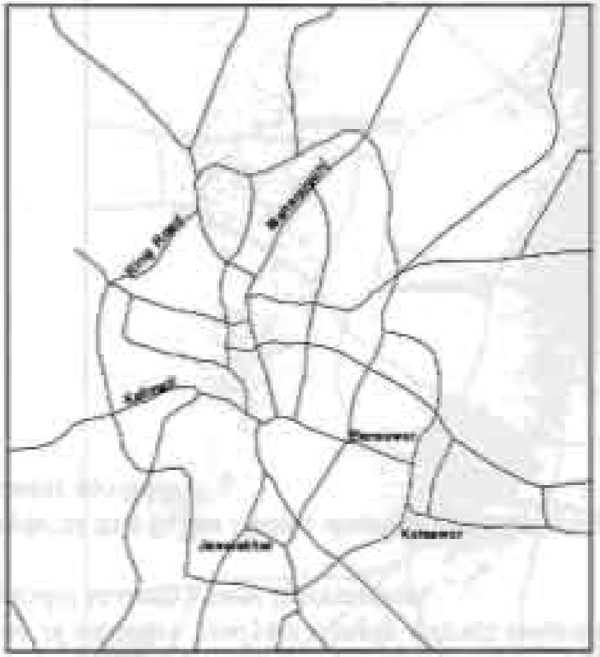
Network models are based on interconnecting logical components, of which the most important are: 'Nodes' define start, end, and intersections; 'Chains' are line features joining nodes; and 'Links' join together points making up a chain. This network can be analysed using GIS. A simple and most apparent network analysis applications are street network analysis, traffic flow modelling, telephone cable networking, pipelines, and so on. The other obvious applications would be service centre locations based on travel distance.

Basic forms of network analysis simply extract information from a network. More complex analysis processes information in the network model to derive new information.

One example of this is the classic shortest-path-between two points problem. The vector mode is more suited to network analysis than the raster model.

Tabular Statistical Analysis

Using Frequency



- What unique categories do I have for streets?
- How many features do I have for each unique category?
- Summarise by using any attribute

Frequency	STRT Code	LENGTH
16	1	128456.326
42	2	698742.302
120	3	8914566.415

Using Frequency

FREQUENCY can be used in TABLES from ARC. FREQUENCY can provide you with unique code occurrences and their frequencies. Optionally, summary items can be totalled for each unique code combination.

Example

Arc: **FREQUENCY**
Usage : FREQUENCY <info_file> <out_file> {case item}
Arc: **FREQUENCY STREET.AAT STREET.FRQ FRQ#**

<u>Enter Frequency items (type END or a blank line when done)</u>

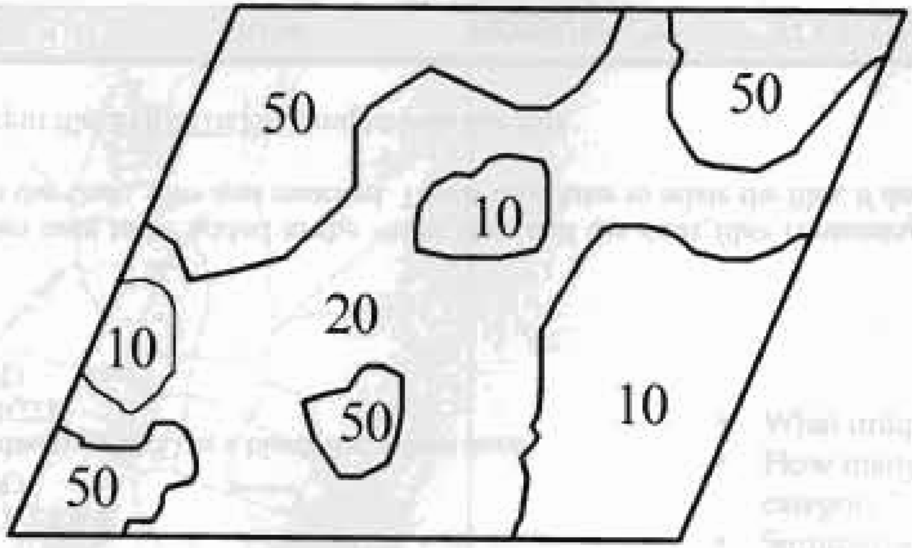
Enter 1st item: STRT_CODE
Enter 2nd item: END
Enter Summary items (type END or a blank line when done)
Enter 1st item: LENGTH
Enter 2nd item: END

NOTE:

The {case item} is an item to be added to the <info_file> and the <out_file> containing the record number in the <out_file> to which the record in the <info_file> was matched. This is used later to relate the files, if desired.

In TABLES, the output file, STREETS.FRQ, might look like this.

$RECNO	FRQ#	FREQUENCY	STRT_CODE	LENGTH
1	1	16	1	128456.326
2	2	42	2	698742.302
3	3	120	3	891456.415



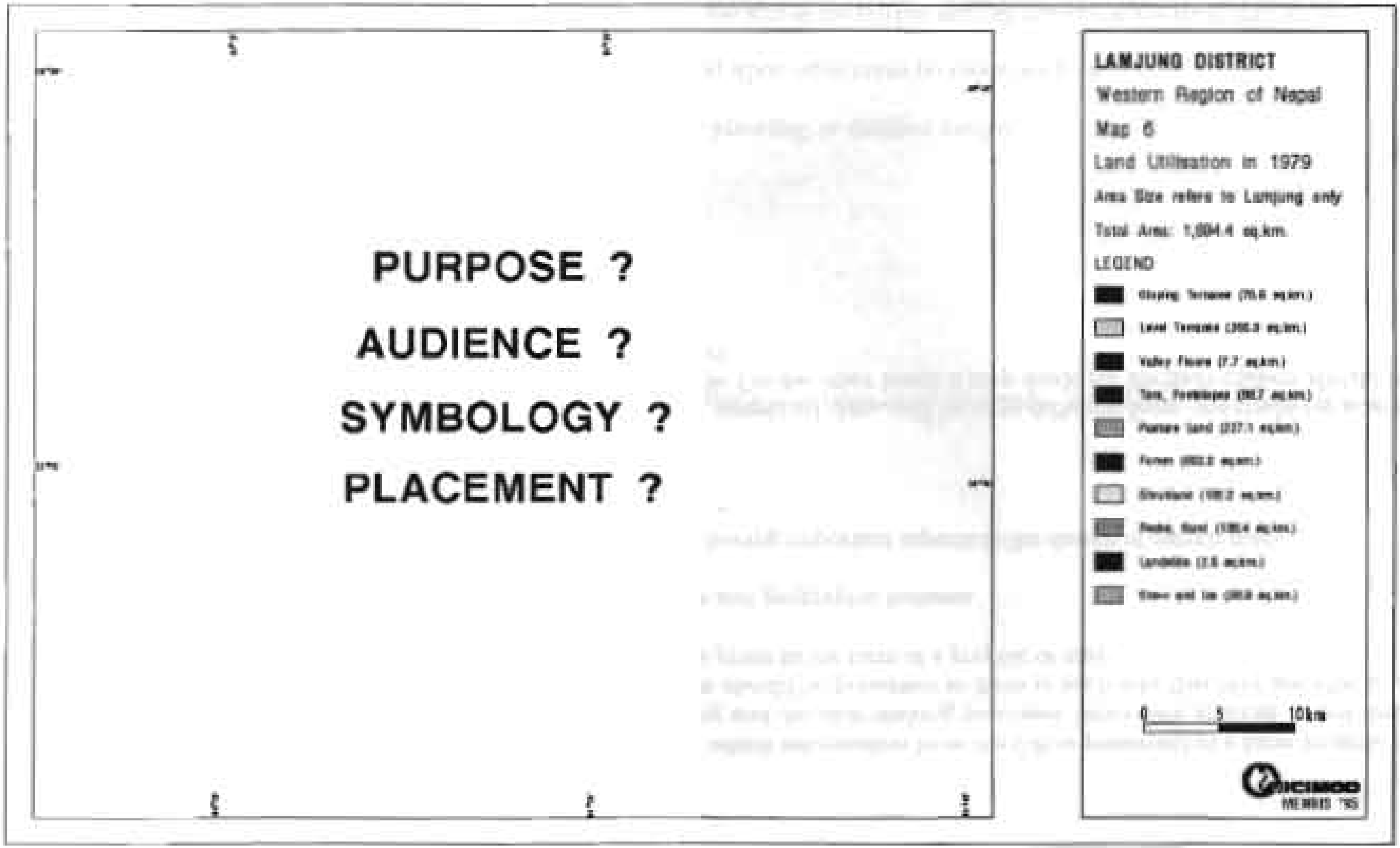
What is the total area of each flood zone?

Flood Zone	Frequency	Sum Area
10	3	100000
20	1	556000
50	4	600000

Chapter 7

Presenting Results of the Analysis

Designing a map layout



Important Aspects in Design of Output Maps

Presenting results of the analysis is the procedure by which information from the GIS is presented in a form suitable for the user. Remember that the results of GIS are used in planning and decision-making processes. Since data analysis is not usually carried out by decision-makers and planners, the information should be presented to them in such way that they are able to make sound decisions. Usually, presentation of the results of GIS is given in the form of a graphic or map.

A map is basically composed of cartographic elements and geographic features.

When you make a map you should be aware of the following important aspects in the design of output maps.

Who is going to use them?

A map intended for school children, containing very simplified data, will be very different from one made for scientists, which should contain as much factual information as possible. On the other hand, a map made for decision-makers should leave out all detail and only present the information relevant to them.

What is their purpose?

- multipurpose (topographic, geologic)
- single purpose (one theme)

What is their content?

- Primary content (main theme)
- Secondary content (base map information)
- Supportive content (legends, scale, etc)

Scale of the map?

Many GIS workers unfortunately still produce maps in A4 size, irrespective of the original scale of the input maps, since it is often most convenient to make a screen dump. Or, they let the size of the output devices determine the final map scale.

The scale of the output map should, however, be based upon other considerations, such as:

- the purpose of the map (for example, regional planning, or detailed design)
- needs of the map user
- map content
- size of the area mapped
- maximum size of the map (format)
- accuracy required

Projection of the map

The projection of the map is of importance when working over large areas. Normally, the selected map projection is that which is also used for topographic maps in a certain country.

Accuracy

1. Positional accuracy: is it at the correct place

    - accuracy of data capture
    - scale of map
    - equipment used

2. Thematic accuracy: is it in the correct unit?

3. Semantic accuracy: cartographically okay?

Cartographic tools and visual variables

A cartographer disposes of the following tools in representating information in a map.

- The basic types of spatial data: points, lines, and areas.
- Volumetrically shaped: mountain shown with hill shading
- Text, for legend information, topographical information and codes of mapping units
- Other symbols, such as pie graphs or bar graphs, to display statistical information within mapping units.

For conveying relevant information about these cartographic tools, a cartographer can use several visual variables. The following visual variables are available.

Position

The position of the point, line, or area features is, of course, given by the information already contained in the map. However, the position of these features in itself gives plenty of information. For example: the distribution of landslides connotes the most susceptible areas.

Form

The form of objects is a very important variable. For example: point features, such as observation points or queries, may be represented by a geometric symbol, a specifically designed symbol, or by text.

The form of the features is also determined by the information on the map. However, the cartographer can manipulate the forms of objects, by generalisation. The form of point, line, or area features is important for reading the map: complex forms attract the eye and suggest complexity; continuous lines imply continuous boundaries; and broken lines imply uncertainty.

Orientation

The orientation of objects can also be manipulated to convey certain information: variation in orientation creates an impression of movement and instability. Orientation is not used very frequently. The most obvious application is the use of dip-strike symbols.

Texture

Texture is defined as the variation in density of the graphical elements under constant value, i.e., with the same overall grey expression. Increased density contrasts attract interest.

Value

The visual variable that refers to the values on a grey scale, ranging from white to black.
Increasing darkness implies increasing importance. The higher the quantitative value, the darker it is represented

Size

The higher the value, the larger the symbol. Thicker lines are more important than thin lines.

Colour

Visual variables of colour:

Hue. The wavelength of a particular colour. What we mean when we refer to colours as red, green, etc. Black, white, and grey are called heels' colours.

Value (Intensity). Also called brightness. The amount of light reflected by a colour. The reflectance value, by comparing the reflectance value with that on a gray scale. We can reduce the value of a colour by adding black to it.

Saturation. The relative pureness of the colour. The degree to which a colour departs from a natural gray of the same value.

What should be on a map?

Thematic information
Topographic information
Geographical location
Legend
Title
Name of author
Year of production
North indication
Scale indication
Location of study area

GIS Output

• Hard copy	Map
• Soft copy	Screen
• Electronic	Module

Data output types

Data are output in one of three (3) formats: viz., soft copy, hard copy, and electronic/digital.

Soft copy output is the format as viewed on a computer screen. This may be text or maps/images in black & white or colour. Because the output is displayed on a computer screen and can be erased from the screen at any time, this type of output is regarded as non-permanent. Soft copy allows the operator to interact and to preview data before its final output.

Hard copy output is a permanent means of display. The information is printed or plotted on paper, photographic film, transparencies, or similar material. Maps/images and tables are usually output in this format.

Electronic output consists of computer-compatible files. Information is stored on a disk, computer compatible tape, optical disk, or any other computer storage media. Although, in general, the information can be erased, the electronic output is considered to be permanent. It is used to transfer data to another computer system, either for additional analysis or to produce hard copy output at another location.

Chapter 8

Implementing GIS

Left Blank

Implementing GIS

- Establishment Phase
  - hardware/software
  - trained manpower
  - pilot study
- Application Development Phase
  - Database Standards
  - Database Development
  - GIS Applications

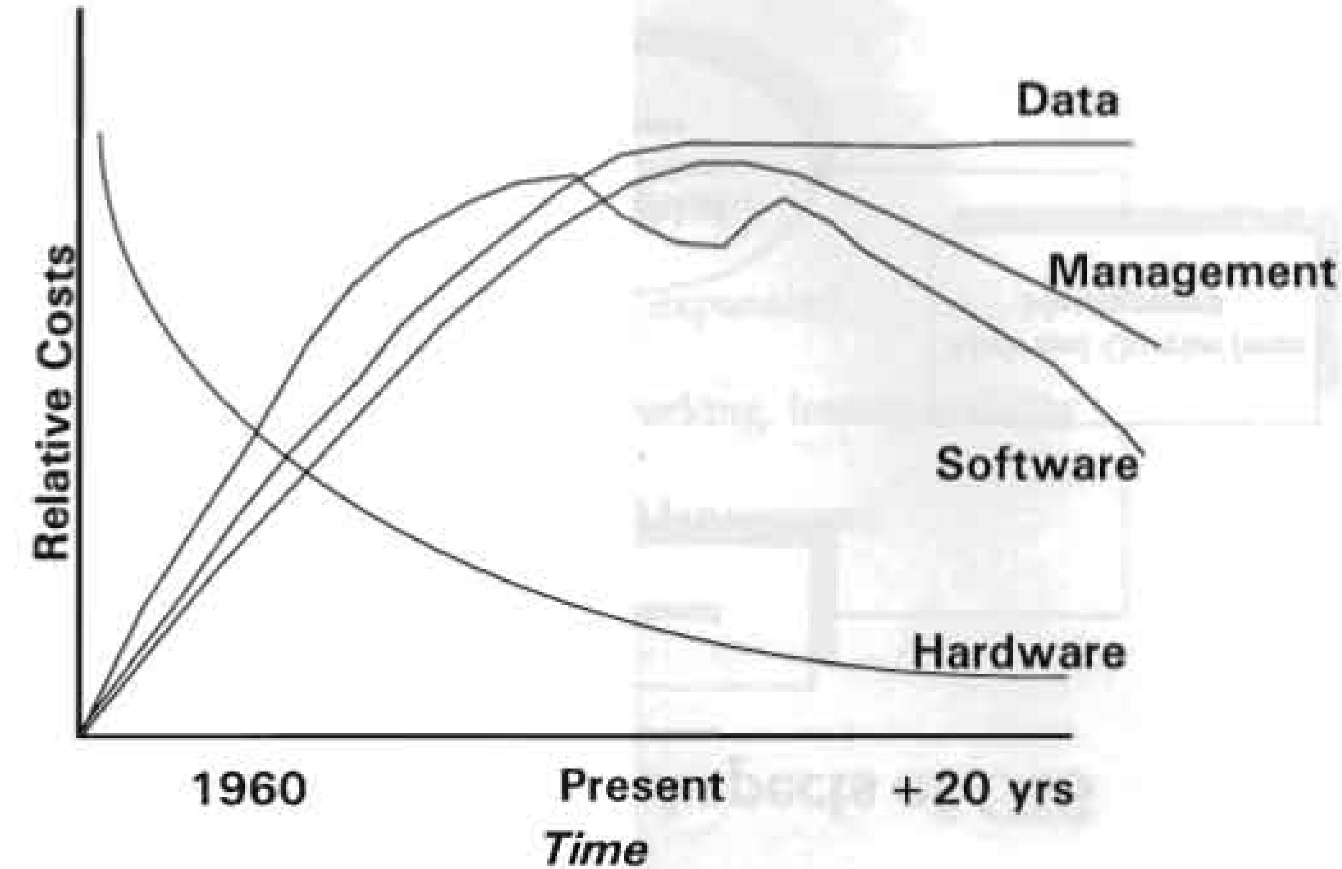
GIS Development Phase

Establishment Phase	Inventory Type Application	Applications for Management
1-2 Years	2-4 Years	4 years onwards

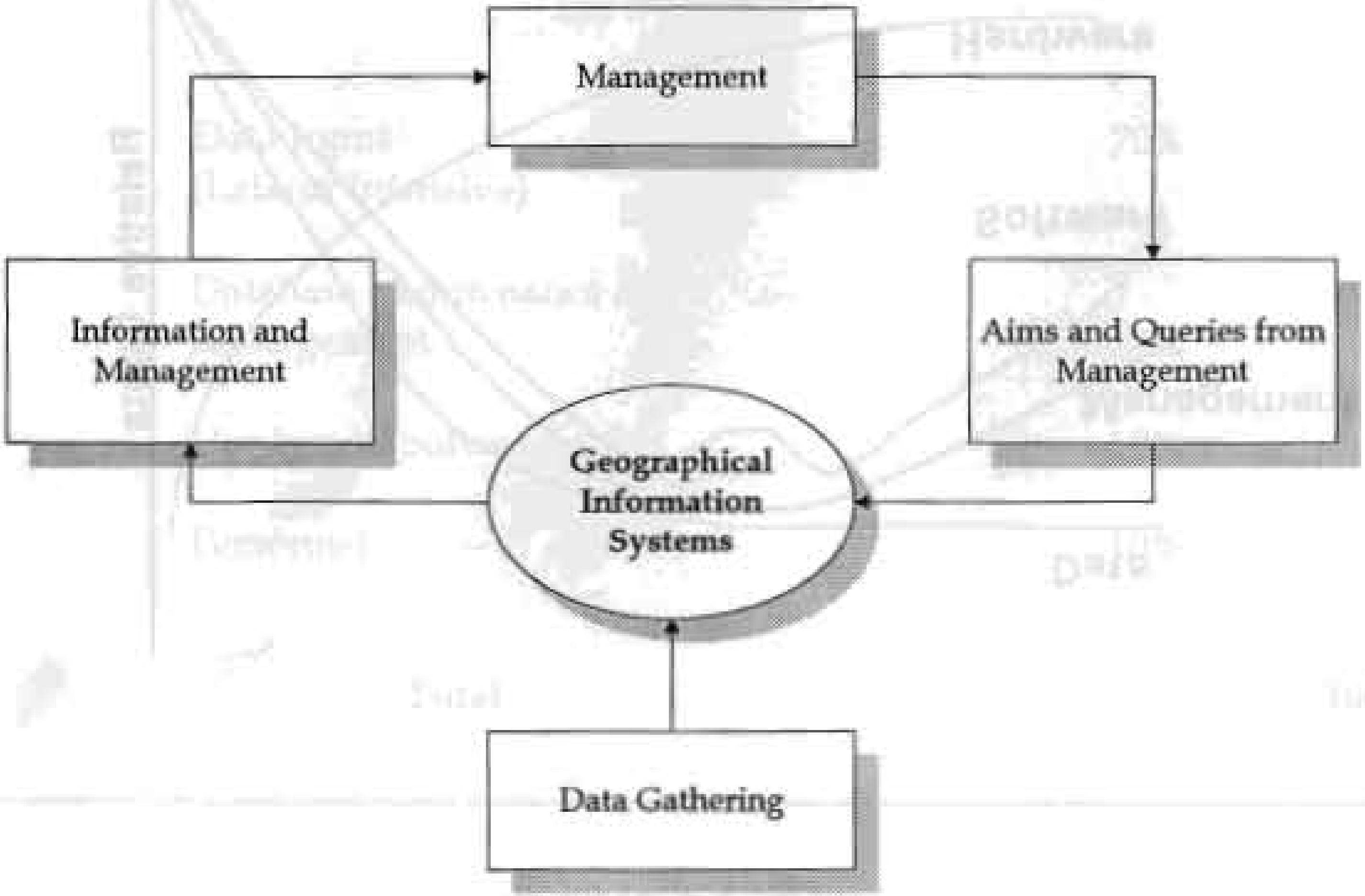
GIS Costs

Data Input (Labour Intensive)	70%
Database Maintenance & Management	10%
Hardware/Software	10%
Personnel	10%
Total	100%

Costs of GIS


Data
Management
Software
Hardware
Relative Costs
1960
Present
+20 yrs
Time

Organisational Aspects of GIS



GIS Technology

Requirements

- Highly Reliable Data Storage
- Flexibility: growth and expansion
- Communication, Networking, Interoperability
- Optimisation for Data Management

GIS Technology

Questions

- Does the system have the software functions required to perform applications?

- Do the hardware components allow you to perform these functions in an efficient manner and provide:

    - growth in respect to data quantities
    - analytical work?

GIS Technology Trends

- Corporate GIS
- Desktop GIS

- Data Transparency
- User Transparency

GIS Technology Trends

- Computer Technology
  - Distributed Computing

    Client-Server Architecture
    Multitasking Capability
  - High Quality Graphics

    3-D or Topographic modelling
  - Network Environment

    Network Transparency
  - Graphical User Interface

    User-friendly Software
    Usability Engineering

GIS Technology Trends

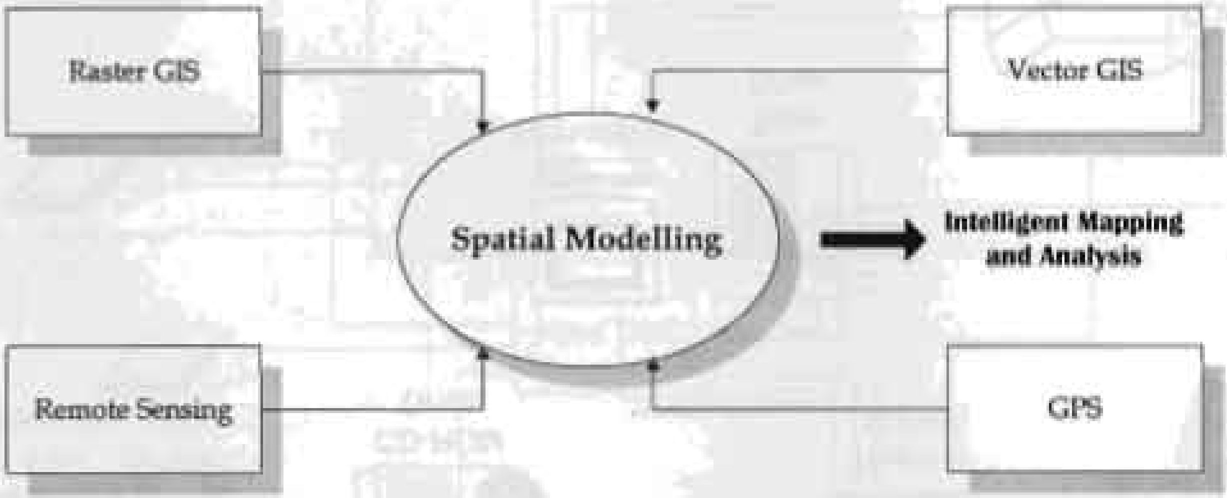
- Database Management Technology
  - Relational Database Management System (RDBMS)
  - Object Oriented Database Technology
- Spatial Modelling
  - Powerful Software Tools
  - Spatial Database Management
  - Artificial Intelligence

    Neural Networks
    Expert Systems

GIS Technology Trends

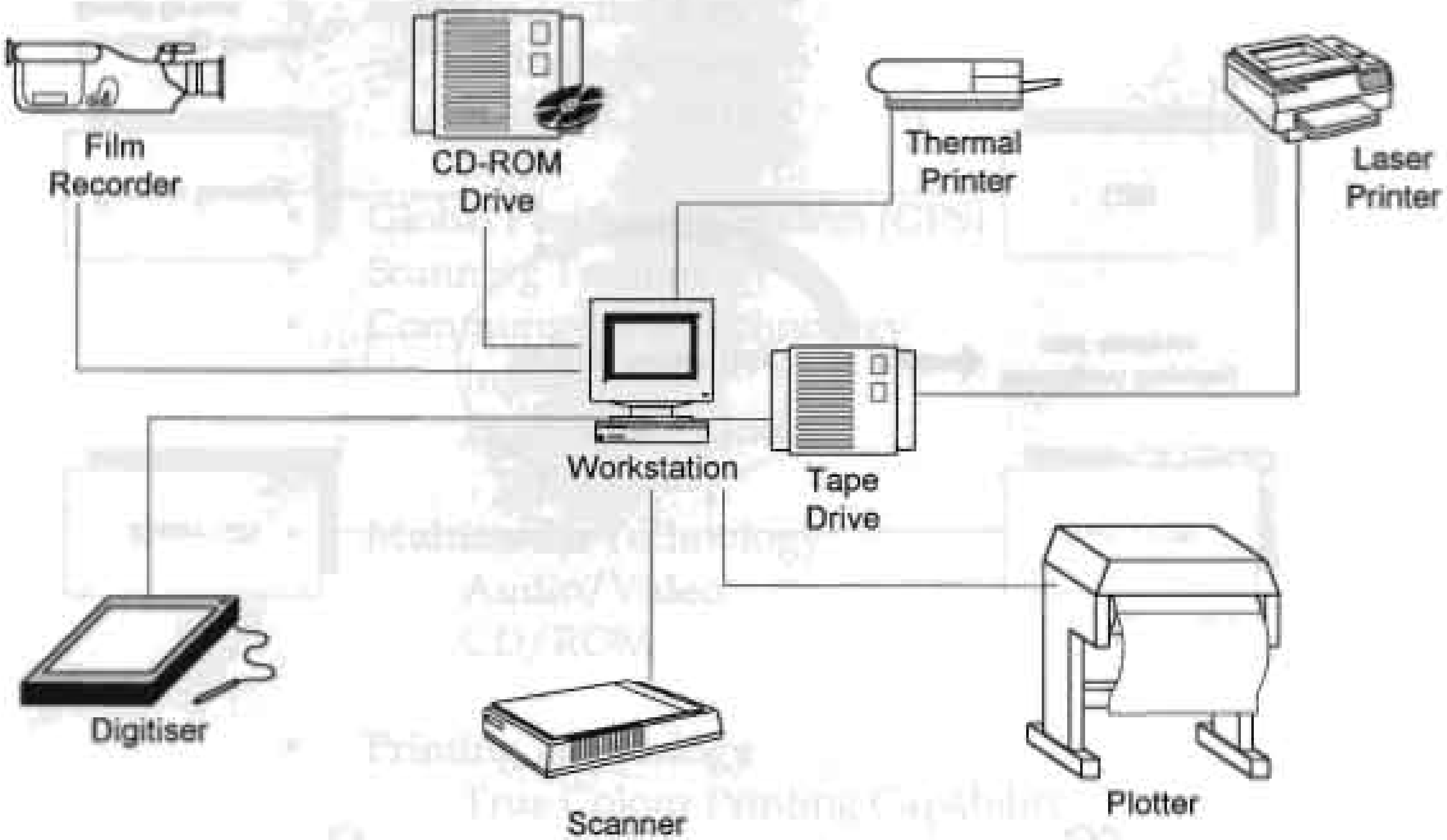
- Satellite Technology
  - Remote Sensing
  - RADAR Satellite
- Global Positioning System (GPS)
- Scanning Technology
- Communication Technology
  - Internet
  - High Speed Modem
- Multimedia Technology
  - Audio/Video
  - CD/ROM
- Printing Technology
  - True Colour Printing Capability

Integration of GIS Technology

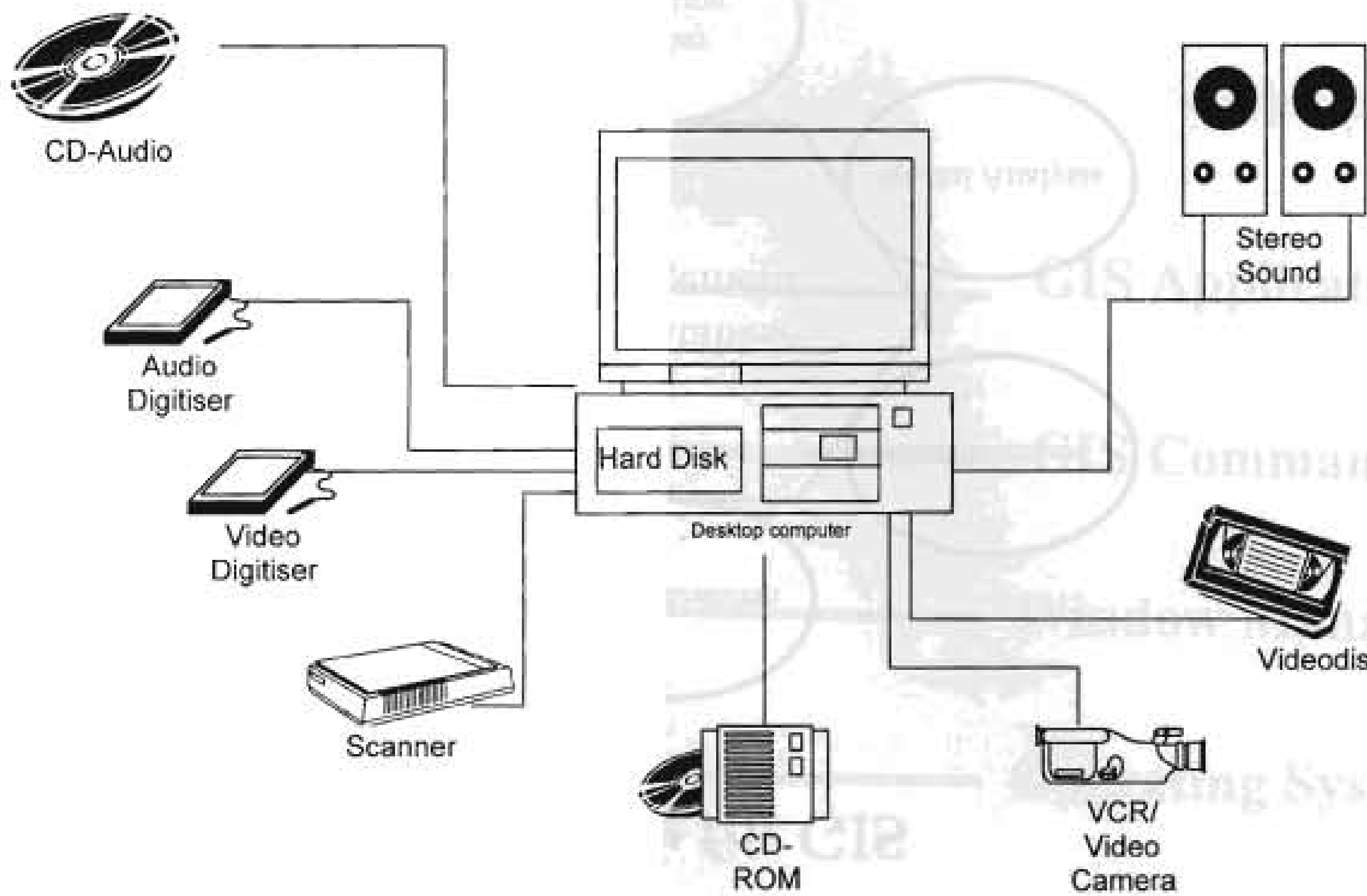


Technology-Driven 1980
Result-Driven 1990

Possible Peripheral Devices

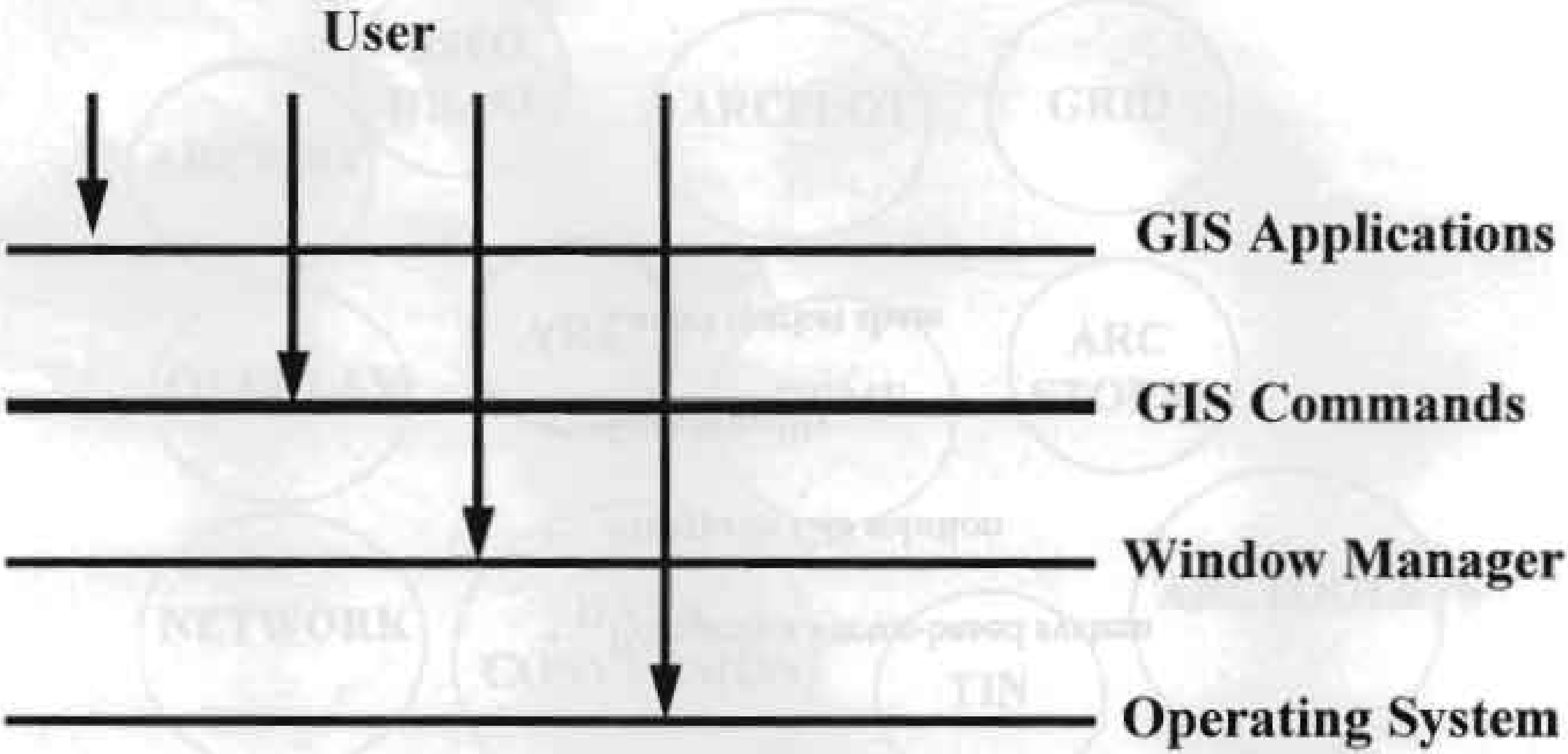


Multimedia GIS



Software for GIS

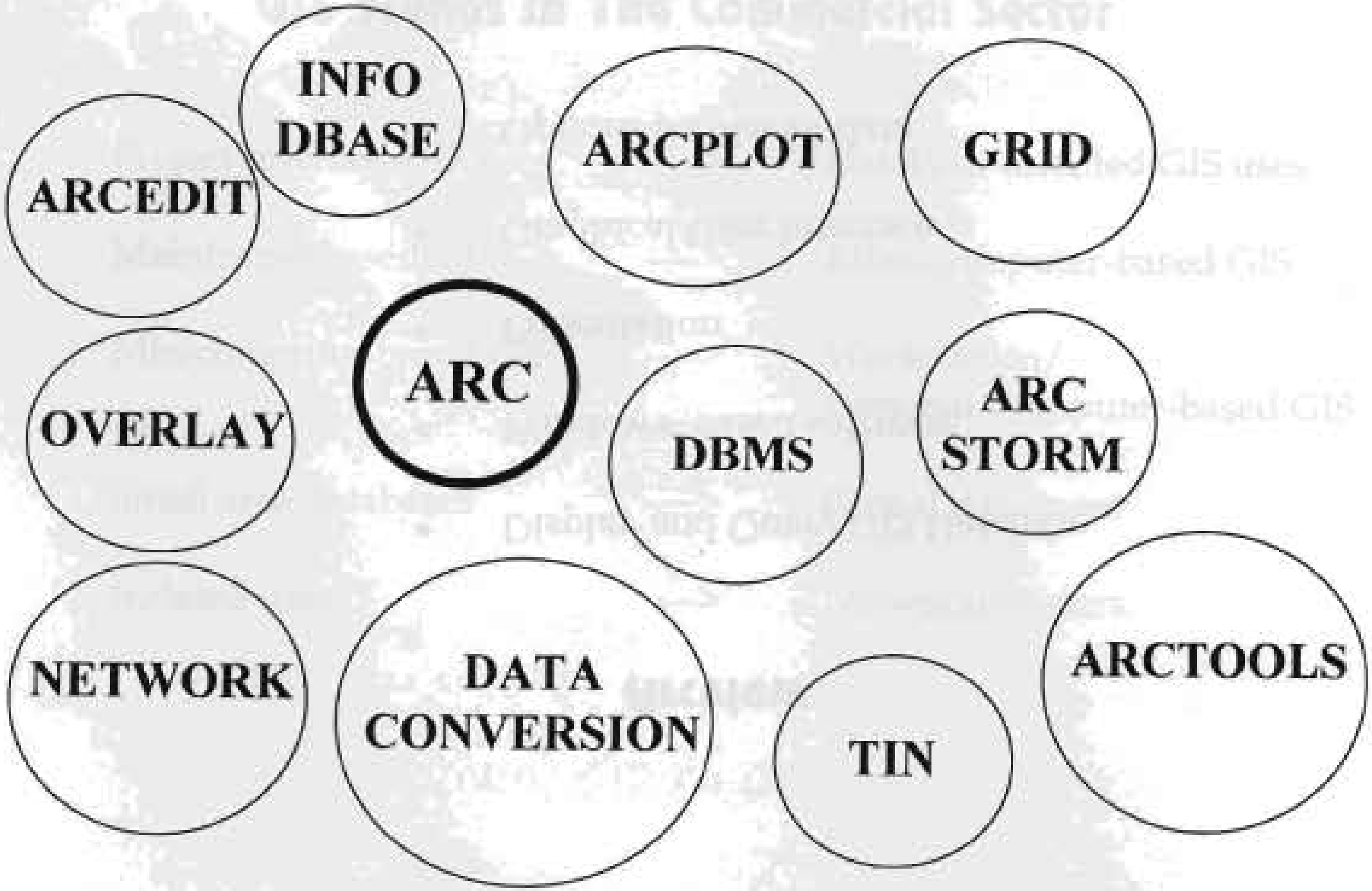
GIS Software Level



Arc/Info

- Primarily a vector-based system
- Enterprise GIS solution
- Functionality
- Larget market share

Arc/Info Modules



Arcview

- Display and Query GIS Database
- Windows' based software
- Presentation
- Graphical User Interface
- Options for Raster data

...Contd.

GIS Trends In The Commercial Sector

Project-oriented GIS uses	---->	Database-oriented GIS uses
Mainframe-based GIS	---->	Mini-Computer-based GIS
Minicomputer-based GIS	---->	Workstation/ Personal Computer-based GIS
Small area databases	---->	Global databases
Isolated users	---->	Networked users.

National GIS Considerations

- Steering Committee
  - A Policy Board
  - Local User Representation
  - University Representation
- Coordinating Agency
  - Training
  - Database Standards and Development
  - Data Distribution and Archiving
  - Technical Advice and Hardware/Software

...Contd.

- Success Stories and Pilot Studies
  - Successful GIS Strategies
  - Local-level Pilot Study
  - Regional-level Pilot Study
  - National-level Pilot Study
- Implementation Strategy and Growth Plan
- Annual Programme of Information Sharing and Programme Assessment

Policy Formation Consideration

- Result Driven Vs. Technology Driven
- Education/Training
- Institutional Framework/Initiative
- Standardisation
- Data Standards

A successful GIS implementation demands a paradigm shift at the Policy and Institutional level

GIS System Development Phase

- Awareness
- Development of System Requirements
- System Evaluation
- Implementation Plan

Database Issues

- Data Standards
- Data Sensitivity
- Data Quality
- Data Dissemination Procedures
- Database Management and Update

GIS Challenges

- Data Capture
- Data Modelling
- Accuracy
- Volume
- Analysis
- User Interfaces
- Costs and Benefits
- Impact on Organisations
- Education and Training

Implementation Alternatives

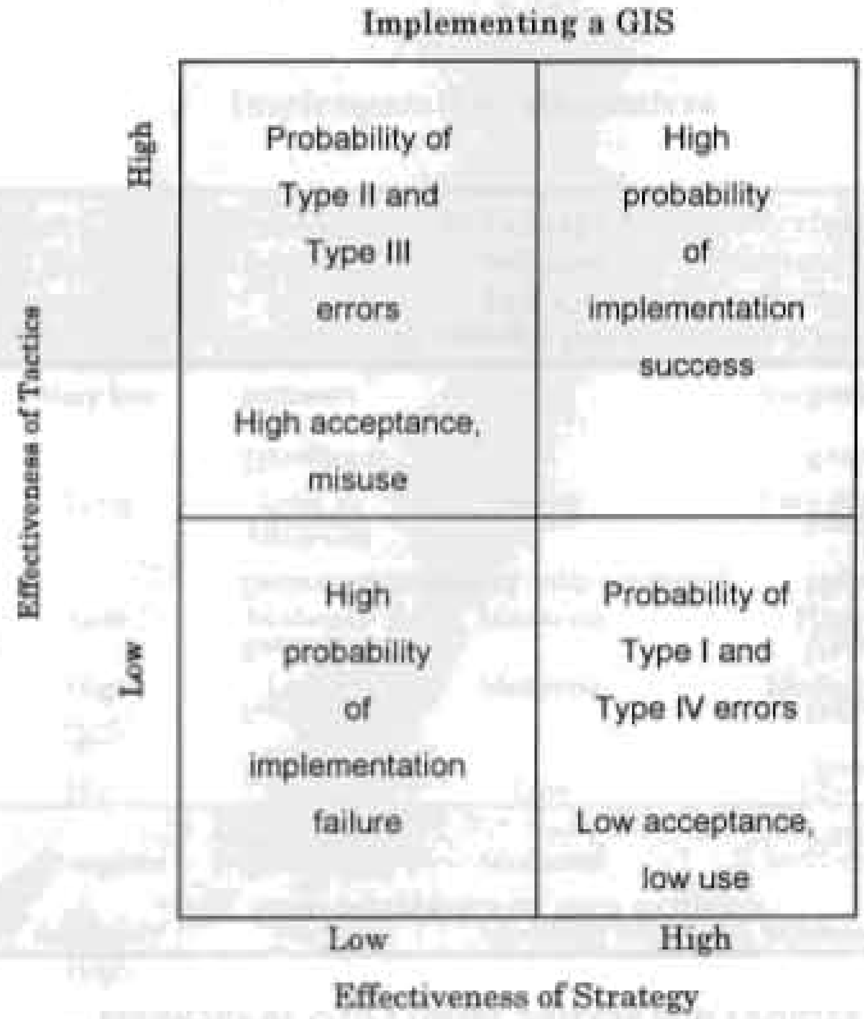
Considerations	User Creates System	Buy Some Software	Buy Complete Software Package	Buy complete Software and Hardware Packages	Purchase GIS Services
Dependence on supplier	Very low	Low	High	Very High	Nearly Complete
Time until system functions	Long	Long to Moderate	Short	Very Short	Not a problem
Initial cost	Low	Moderate	Moderate	High	High
Labour costs paid by user	High	Lower	Moderate	Moderate	Very low
Risk and uncertainty	High	Lower	Low	Low	Low
Customising	Complete	Complete	Moderate	Moderate	Varies
Technical skill required of user	Extremely High	High	Moderate	Moderate	Quite Low
Use of existing resources	High	High	Moderate	Low	Very Low

Source: ***Adapted from Dangermond and Smith 1980***

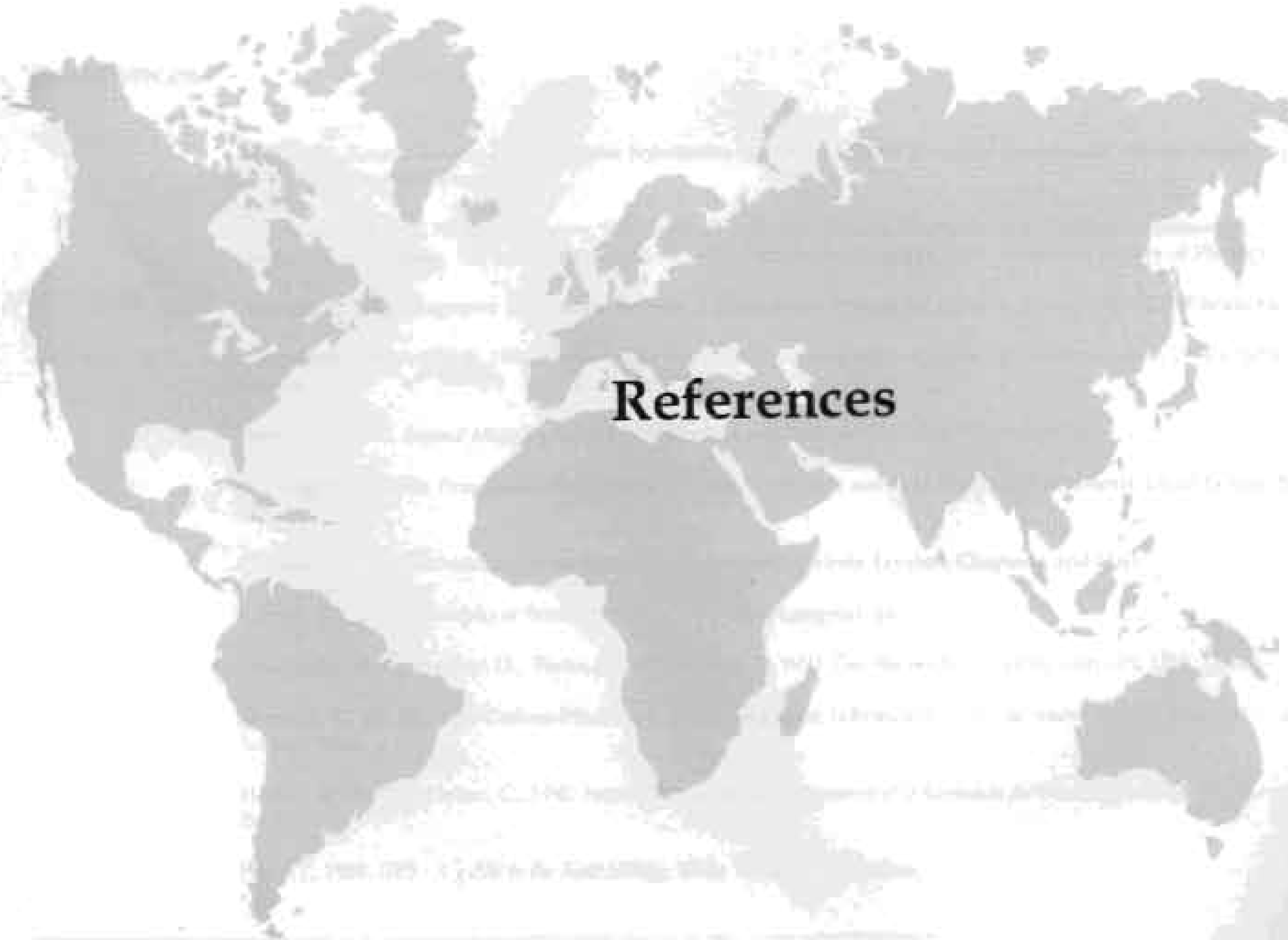
Elements of GIS Project Success and Failures

Characteristics of GIS Projects		
Activity	Success	Failure
Planning	Rigorous	'Run and gun' style
Requirements	Focussed	Diffused
Appraisal of effort	Realistic	Unrealistic
Staffing	Dedicated, motivated, high continuity	High turnover
Funding	Adequate	Inadequate, conjectural
Time estimates	Thoughtful	Rushed or prolonged
Expectation	Balanced	Exaggerated

Source: *Antenucci, Brown, Croswell, and Kevany (1991). Copyright 1991 by Chapman & Hall, reprinted by permission*



Strategy/tactics effectiveness matrix. From Schultz, Sleving, and Pinto (1987). Copyright 1987 by Randy L. Schultz, Dennis P. Slevin, and Jeffrey K. Pinto. Reprinted by permission.



References

References

ADB, 1991. *Remote Sensing and Geographic Information System for Natural Resources Management.* Environment Paper No 9. Rajan, M. S. (ed). Manila, Philippines: ADB.

American Society of Photogrammetry, 1983. *Manual of Remote Sensing;* Second Edition; Volume I. Simmonett, D. S., and Ulaby, F. T. (eds). Volume II, Estes, J.E. and Thoreley, G. A. (eds). Fall Church Virginia, USA: American Society of Photogrammetry.

Aronoff, S., 1989. *Geographic Information Systems A Management Perspective.* Ottawa , Canada: WDL Publications.

Asian Development Bank, 1994. *Hindu Kush Himalayan Environmental Geographic Information System,* 1994 Final Report, RETA 5481. Manila: ADB

Berry J. K., 1993. *Beyond Mapping Concepts, Algorithms and Issues in GIS.* USA: GIS World Inc.

Burrough P.A., 1986. *Principles of Geographical Information Systems and Land Resources Assessments.* Great Britain: Butler and Tanner Ltd.

Cassatari, S., 1993. *Introduction to Integrated Geo-Information Systems.* London: Chapman and Hall.

Curran, P.J., 1985. *Principles of Remote Sensing.* N.Y., USA: Longman Inc.

Goodchild, M. F., Bradley, O., Parks, L., and Steyaert, T., 1993. *Environmental Modelling with GIS.* USA: Oxford University Press.

Green, D.R., Rix, D., and Cadous-Hudson, J., 1994. *Geographic Information 1994, The Source Book of GIS, AGI.* Great Britain: Burgess Science Press.

Hassan M. H., Hutchinson, C., 1992. *Natural Resources and Environment Information for Decision-making.* Washington DC: World Bank.

Hurn, J., 1989. *GPS - A guide to the Next Utility.* USA: Trimole Navigation.

Japanese Association of Remote Sensing, 1993. *Remote Sensing Note*. Tokyo, Japan: Japanese Association on Remote Sensing.

Lillesand, T. M., and Kiefer, R. W., 1979. *Remote Sensing and Image Interpretation*. N.Y., USA: John Wileys & Sons.

Maguire, D.J. and Goodchild, M.F., 1993. *Geographical Information Systems and Applications*. Great Britain: Bath Press.

Price, M. F. and Heywood, D. I, 1994. *Mountain Environments and Geographic Information Systems*. Great Britain: Burgress Science Press.

Sabins, F. F. Jr., 1986. *Remote Sensing Principles and Interpretation;*. N. Y., USA: W. H. Freeman and Company.

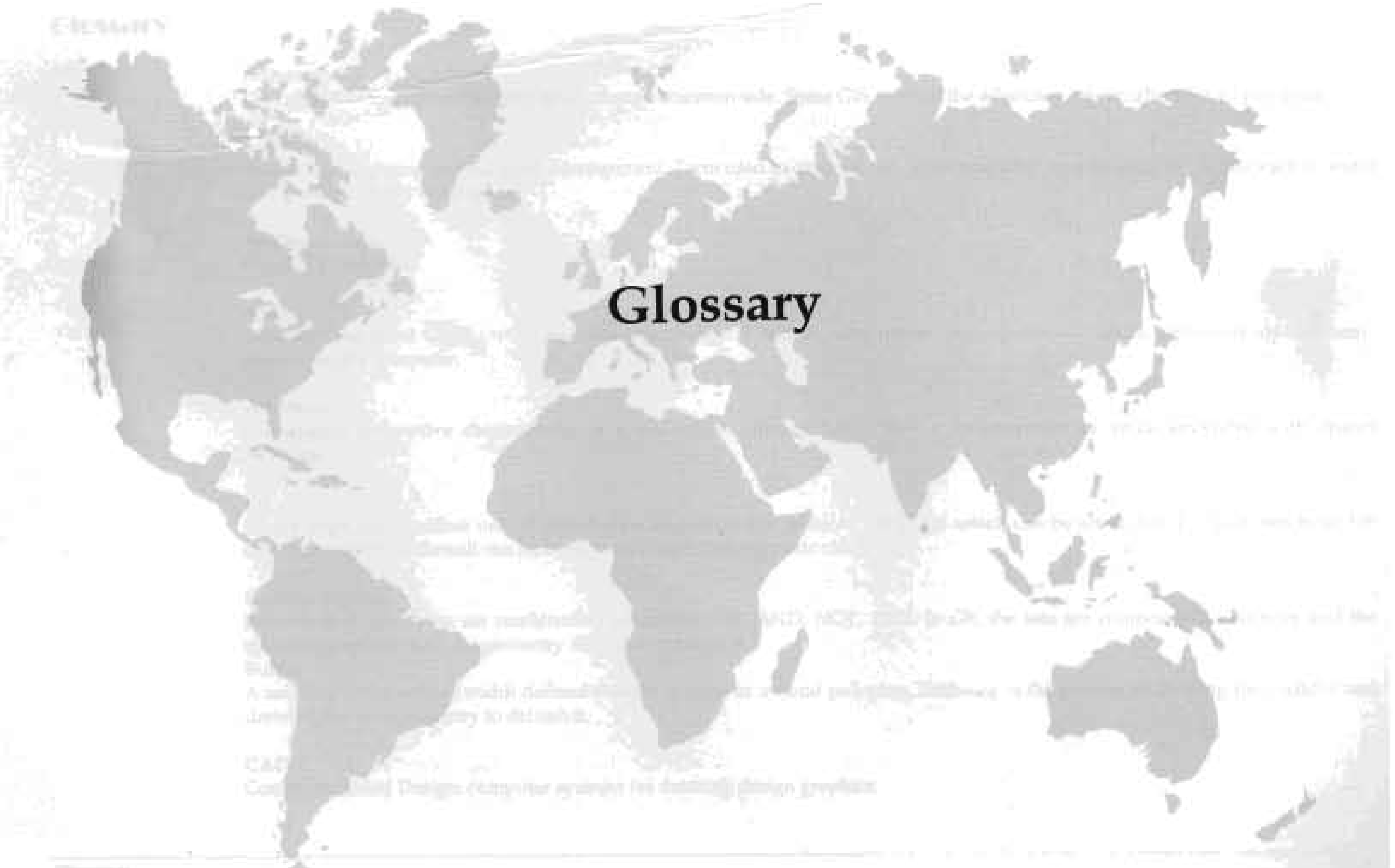
Scholten, H. J. and Stillwell, J. C. H., 1990. *Geographic Information Systems for Regional and Urban Planning*. The Netherlands: Kluwer Academic Publishers.

Short, N.M., 1982. *The Landsat Tutorial Workbook, Basics of Satellite Remote Sensing*. NASA Reference Publication 1078. Washington, DC, USA: NASA.

Siegal, B.S., and Gillespie, A. R., 1980. *Remote Sensing in Geology*. USA: John Wiley & Sons, Inc.

Swain, P. H. and Davis, S. M. (eds), 1979. *Remote Sensing : The Quantitative Approch*. USA: McGraw-Hill Book Company.

Glossary



Glossary

Adjacency
Describes whether two areas (polygons) share a common side. Some GIS store all the adjacency relationships for all polygons.

AM/FM
Automated Mapping and Facilities Management. Term used to describe the digital mapping systems used in utilities such as water or electricity supply companies.

Analogue maps
Maps in paper form.

ASCII
American Standard Code for Information Interchange: a widely used industry-standard code which represents alphanumeric characters in a computer.

Attribute
Non-spatial descriptive characteristic of a real-world phenomenon. Often a measurement or value associated with spatial locations.

Bit
Binary digit. The smallest unit of information representation within a computer which can be set to 0 or 1. Seven bits have 128 different combinations and can be used to represent alphanumeric characters.

Boolean algebra
A method of specifying set combination operations: OR, AND, NOT, XOR. In GIS the sets are composed of geometry and the operations specify how the geometry should be combined.

Buffer
A corridor of a specified width defined parallel to lines or around polygons. Buffering is the process of defining the corridor and drawing the new geometry to delimit it.

CAD
Computer Aided Design: computer systems for drawing design graphics.

CCD
Charge Coupled Device: a device used in scanners to sense light/dark or colour contrast on a scanned map.

Choropleth
Map shaded by a density according to value.

Connectivity
Describes whether sets of points (nodes) or lines are connected to each other.

Coordinate pair (X, Y)
A pair of coordinates describing the location of a point feature on x and y axes. Sets of coordinate pairs are used to define lines and polygons.

Coordinate system
A particular type of reference frame, often grid-based, that uses linear or angular quantities to designate the position of points within the frame of reference.

Coverage
A collection of data describing spatial features stored in the same map file (primarily used by ESRI in ARC/INFO systems).

CPU
Central Processing Unit: the part of the computer that controls the flow of data and performs the computations.

CRT
Cathode Ray Tube: similar to a television picture tube, on which an image is displayed.

Cursor
The hand-held, movable part of a digitiser with cross hairs in a small window used for the accurate designation of points on an image or map.

Database
An organised, integrated collection of data related by a common fact or purpose.

Database Management System (DBMS)
A collection of computer software for organising and accessing the information in a database.

Data capture
The encoding of data or the conversion of map data to digital data, both spatial and non-spatial aspects.

Data dictionary
This contains information about definition, structure and usage of data in a database. No data is actually held here.

Data model
An abstraction of the real world which incorporates only those properties thought to be relevant to the application in hand. Also, a set of guidelines for the representation and logical organisation of data in a database, consisting of named logical units of data and the relationships between them. In GIS, this term usually refers to a set of spatial features with associated characteristics.

Data quality
The quality of the data measured in relation to the actual phenomenon measured at source.

Dataset
A named collection of logically related features arranged in a prescribed format.

Data structure
Detailed and low-level descriptions of spatial storage structures and the operations possible upon them.

DEM
Digital Elevation Model: a digital representation of a surface as a regular grid of elevation values.

Digital map data
A collection of digital information about real-world spatial phenomena.

DTM
Digital Terrain Model: a digital representation of ground surface relief enhanced by the addition of topographic information.

Digitiser
A device (usually electronic) for coding point locations on a graphic image or map to plane (x, y) coordinates.

DOS
Disk Operating System: the software which controls the transfer of data between main memory and disk. MS-DOS™ is the most common form of operating system for personal computers.

Edge matching
The comparison and adjustment of features to obtain agreement along the edges of adjoining maps.

Editing
Inserting, deleting and changing geometry and attributes to correct and/or update a model or database.

Electro-magnetic spectrum
The spectrum of wavelengths of electromagnetic radiations (including infrared, visible and ultraviolet light).

Electrostatic printer/plotter
A device for printing graphic images by placing a grid of small electrical charges on the paper so that a dark or coloured powder, or toner, will adhere in these places.

Entity
A real-world phenomenon perceived or perceivable by human agency.

Error
Various forms of discrepancy between real-world phenomena and a database. Error can be introduced into a spatial database during capture and processing.

Feature
A real-world phenomenon, named and classified. Often used in cartography to name classes of elements shown on a map.

Feature code
An attribute specifying the type of feature recorded in a GIS. Cartographic agencies define feature codes to standardise the description.

Field
A subdivision of a record which contains a unit of information. A characteristic measure for all records.

File
A collection of records, each of which can be referenced according to its position in the file.

Filtering
A method of changing the level of detail or extraction of information from a spatial (normally raster) dataset.

Generalise
Reduce in detail, simplify or resample to change the level of information in a dataset. The most common generalisation operation is line-thinning by discarding coordinates.

Geographic information
Information which can be related to a location (defined in terms of point, line, and area), particularly, information on natural phenomena, cultural or human resources.

Geographical Information System (GIS)

- a set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of circumstances (Burrough 1986)

Geometry
A system for the manipulation of points and lines defined by a set of axioms.

Global Positioning System (GPS)
A GPS is a position-fixing system which uses the time taken for signals to travel from at least three GPS satellites in a known orbit to a receiver on the ground.

Hardware
The physical device used to process a computer programme and display the results.

Heads-up digitising
Heads-up digitising systems automatically convert strips of raster pixels to vector data by tracing them on screen.

Image processing
Encompasses all the various operations that can be applied to image or raster format data. These include image compression, restoration, enhancement, rectification, preprocessing, quantisation, spatial filtering and other image pattern recognition techniques.

Ink-jet printer/plotter
A display device that prints out characters and grey tones as patterns of small dots formed by tiny drops of ink sprayed onto the plotting medium.

Interactive
Describes a process of two-way communication between the user and the computer.

Interface
An electronic translator of the signals of two devices, such as a computer and a plotter, so that otherwise incompatible information can be transferred between them; or a screen format for the display and communication of commands to the computer.

Interpolation
The procedure of estimating the values of unknown points on a surface from the values of a number of points of known value.

Isoline
A line joining points of equal value.

Isometric models
A model of a scene or object scaled to reality.

KBS
Knowledge Based System: a system based upon rules, defined and structured for use in making inferences in restricted knowledge domains.

LAN
Local Area Network: a network linking computers together in a small area (usually a single building).

Layer
Usually represents a theme or feature type within a database. Layers which are registered to the same coordinates as other layers can be integrated in different ways to create a new layer.

Line
The shortest distance between two points (sometimes called a line segment). In some GIS, many connected line segments are also referred to as a line. A one-dimensional object.

LIS
Land Information System: a system for handling land ownership (cadastral) data.

Map algebra
A set of operations for manipulating, filtering, and combining raster maps devised by Tomlin and used in many GIS.

Map projection
A transformation from a spheroid to a flat plane representing the parallels of latitude and the meridians of longitude of the earth.

Menu
A list of available options displayed on a terminal or a set of preprogrammed areas on a digitiser.

Mouse
A device used to move a screen cursor and to input commands; commonly used in graphical operations.

Network analysis
Analytical techniques concerned with the relationships between locations on a network, capacities of network systems and the best location for facilities on a network.

Object-oriented programming
Object-oriented programming is a language design which has been used to develop database management systems and application programmes such as GIS. Object-oriented software has data 'encapsulated' with operations, and commands are executed using message passing.

Overlay
The process of integrating digital representations of various spatial data registered to a common coordinate system.

Pixel
Short for Picture Element, ie, the smallest discrete element that makes up an image. It may represent either a small square or portion of the earth's surface, scanned by satellite or aircraft, a portion of a graphics image sensed by an optical scanner or an individual dot on a screen.

Point
The position or location of an object in a spatial reference system. A zero-dimensional object.

Polygon
An area with three or more sides intersecting at the same number of points. A two-dimensional object.

Projection
The procedure for transferring features from the spherical earth to a flat plane using mathematical transformations.

Quadtree
A structure to compress and spatially index raster data. Constructed by dividing a (square) area of data recursively until a quadrant is completely full or empty.

Query
A structured enquiry made on a map or database using a formal language.

Raster data
Data expressed as an array of pixels with spatial position implicit in the ordering of pixels.

Rasterisation
The process of converting vector data into raster form.

Record
A set of observations on a real-world phenomena as described by attributes.

Relational database
A database of tables which can be linked together through common attributes.

Remote sensing
The technique of obtaining data about the environment and surface of the earth from a distance, e.g., from an aircraft or satellite.

Resolution
Level of discrimination in the representation of objects, generally spatial.

Scale
The ratio or fraction between the distance on a map, chart or photograph and the corresponding distance on the surface of the earth.

Scanner
The electronic device used to convert analogue information from maps or images into a digital format usable by a computer.

Scanning
A method of data capture whereby an image or map is automatically registered and converted into digital raster form.

Sliver polygon
Formed when two polygons which have been overlaid do not abut exactly but overlap along one edge and leave a small space between the two.

Software
A system of programmes used to execute tasks written for the computer.

Spatial analysis
Analytical techniques associated with the study of locations of geographical phenomena together with their spatial dimensions.

Spatial data
Data relating to the location of geographical phenomena together with their spatial dimensions.

SQL
Structured Query Language: a language for the manipulation, update and querying of the data in relational database tables. ISO standard 9075 (1987).

Standards
A fixed quantity or quality, applied to data. Standards serve as a reference or rule and establish practices or procedures to evaluate results.

Terrain modelling
The creation of a realistic terrain representation for computer display.

Tessellation
The subdivision of geographic space using either regular or non-regular methods.

Thiessen polygon
A polygon bounding the region closer to a point than to any other adjacent point.

Tile
A regular- or irregular-shaped spatial unit within a geographical database.

TIN
Triangular Irregular Network: the most equilateral set of triangles possible joining a set of points.

Topographic map
A map showing the features which describe the surface of a particular place or region.

Topological structuring
The process of organising data so that the relationships of connectivity, adjacency and containment are encoded and stored.

Topology
The location of geographic phenomena relative to each other but independent of distance or direction. Includes relationships of connectivity, adjacency, and containment.

Transformation
Mathematical conversion of coordinates between alternative referencing systems. Affine transformations keep straight lines straight, and curvilinear ones may make straight lines curved (e.g. as in map projection).

Triangulation
The interconnection of all points within an area to form a set of reproducible triangles.

UNIX
An operating system of software used commonly for workstations.

Variable
A discrete measurement on a parameter.

VDU
Visual Display Unit: a screen display for a computer.

Vector data
A description of spatial phenomena based upon geometry.

Vectorisation
The process of converting raster data into vector form.

Window
A frame with a specified size and location on the screen of an interactive graphics system and within which a rectangular portion of the 'map' is displayed.

Work station
A powerful computer with integral processing and data storage and a high resolution screen.

Acronyms

Acronyms

AATSR	Advanced Along Track Scanning Radiometer
AMI	Active Microwave Instrument
ATSR/M	Along Track Scanning Radiometer/Microwave Sounder
AVHRR	Advanced Very High Resolution Radiometer
AVNIR	Advanced Visible Radiometer
BIL	Band Interleaved by Line
BIP	Band Interleaved by Pixel
BSQ	Band Sequential
CCD	Charged Coupled Device
CCT	Computer Compatible Tape
CD-ROM	Compact Disk Read Only Memory
CRT	Cathode Ray Tube
DAT	Digital Audio Tape
DCP	Data Collection Platform
DCS	Data Collection System
DEM	Digital Elevation Model
DN	Data Number
DPC	Data Processing Centre
DTM	Digital Terrain Model
EMS	Electro Magnetic Spectrum
EMW	Electro Magnetic Wave
EOS	Earth Observation System
ERBE	Earth Radiation Budget Experiment
ERM	Electro Magnetic Radiation
ERS	European Remote Sensing Satellite
ERTS	Earth Resources Technology Satellite (Later named Landsat-1)
ESA	European Space Agency
ETM	Enhanced Thematic Mapper

FOV	Field of View
GIS	Geographic Information System
GMS	Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
GOMOS	Global Ozone Monitoring System
GPS	Global Positioning System
GRS	SPOT Grid Reference System
GVI	Global Vegetation Index
HDDT	High Density Digital Tape
HIRS	High Resolution Infrared Radiation Sounder
HRV	High Resolution Visible
HRVIR	High Resolution Visible and Middle Infrared
HSI	Hue, Saturation, Intensity
ICIMOD	International Centre for Integrated Mountain Development
IFOV	Instantaneous Field of View
INSAT	Indian National Satellite
IR	Infrared
IRS	Indian Remote Sensing Satellite
JERS	Japanese Earth Resources Satellite
LFC	Large Format Camera
LIDAR	Light Detection and Ranging
LIS	Light Imaging Sensor
LISS	Linear Imaging Scanner System
MENRIS	Mountain Environment and Natural Resources' Information Service
MERIS	Medium Resolution Imaging Spectrometer
MESSR	Multispectral Electronic Self Scanning Radiometer
MO	Magneto Optical Disk
MOS	Marine Observation Satellite

MSR	Microwave Scanning Radiometer
MSS	Multi Spectral Scanner
MSU	Microwave Sounding Unit
MTF	Modulatin Transfer Function
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NDVI	Normalized Difference Vegetation Index
NEP	Noise Equivalent Power
NOAA	National Oceanic and Atmospheric Administration
NOAA	NOAA Satellite
NRCT	National Research Council of Thailand
NRSA	National Remote Sensing Agency of India
NVI	Normalized Vegetation Index
OPS	Optical Sensor
PA	Panchromatic
PC	Personal Computer
RA	Radar Altimeter
RADAR	Radio Detection And Ranging
RBV	Return Beam Videocon camera
S/N	Signal to Noise ratio
SAR	Synthetic Aperture Radar
SBUV	Solar Backscatter Ultra-Violet Experiment
SLAR	Side Looking Airborne Radar
SMMR	Scanning Multichannel Microwave Radiometer
SPOT	Systeme Probatoire d'Observation de la Terre
SSU	Stratospheric Sounding Unit
TDRS	Tracking and Data Relay Satellite
TFOV	Total Field of View

TIN	Triangulated Irregular Network
TIROS	Television and Infrared Observation Satellite
TM	Thematic Mapper
TOVS	TIROS Operational Vertical Sounder
UNEP	United Nations Environmental Programme
UNEP/GRID	UNEP/ Global Resource Information Database
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator Coordinate System
UV	Ultraviolet
VIRR	Visible and Infrared Radiometer
VIRS	Visible and Infrared Scanner
VIS	Visible
VISSR	Visible Infrared Spin Scan Radiometer
VNIR	Visible and Near Infrared Radiometer
VTIR	Visible and Thermal Infrared Radiometer
WMO	World Meteorological Organization
WORM	Write Once Read Many disk
WRS	World Reference System
WS	Workstation
XS	Multispectral

Participating Countries of the Hindu Kush-Himalayan Region

- Afghanistan
- Bhutan
- India
- Nepal
- Bangladesh
- China
- Myanmar
- Pakistan

International Centre for Integrated Mountain Development (ICIMOD)
4/80 Jawalakhel, G.P.O. Box 3226, Kathmandu, Nepal

Telephone : 977 1 525313
Facsimile : 977 1 524509
977 1 524317

Telex : 2439 ICIMOD NP
Cable : ICIMOD NEPAL