An Introduction to

Geographic Information System

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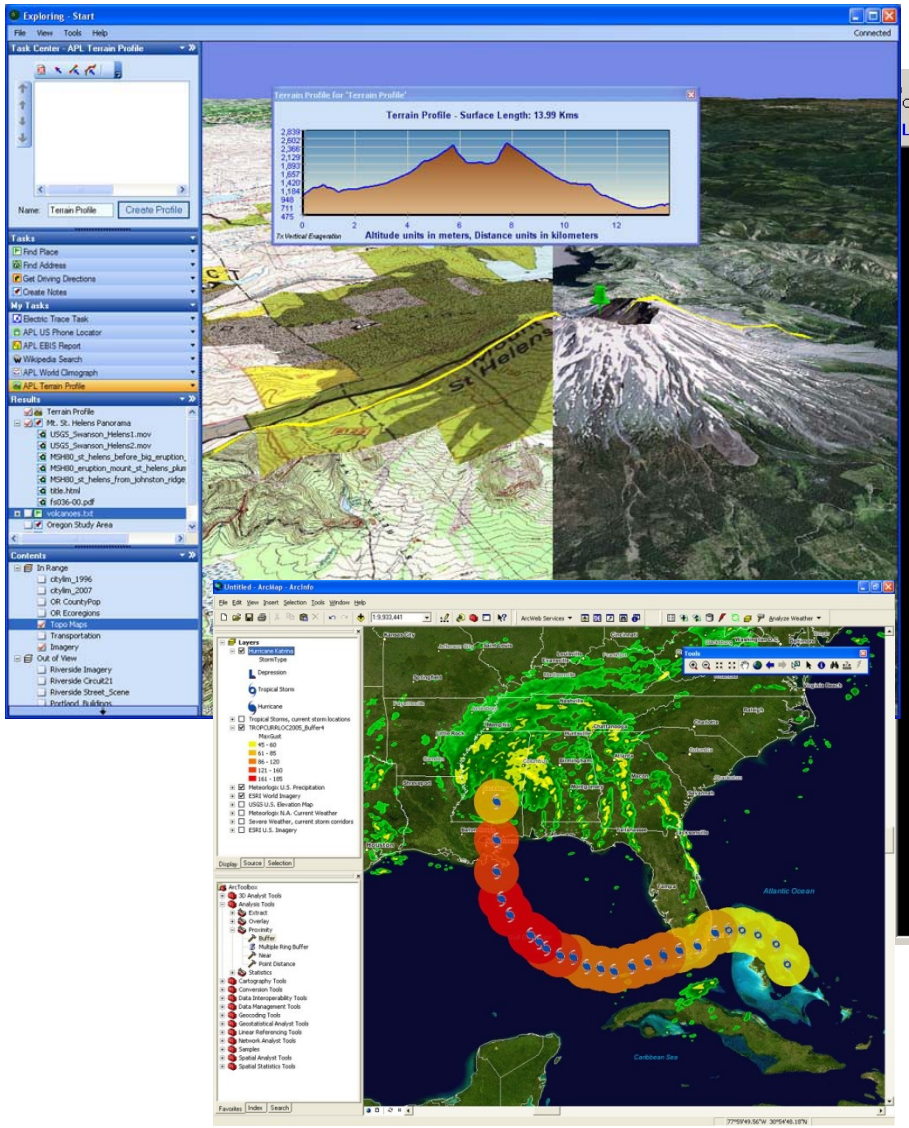
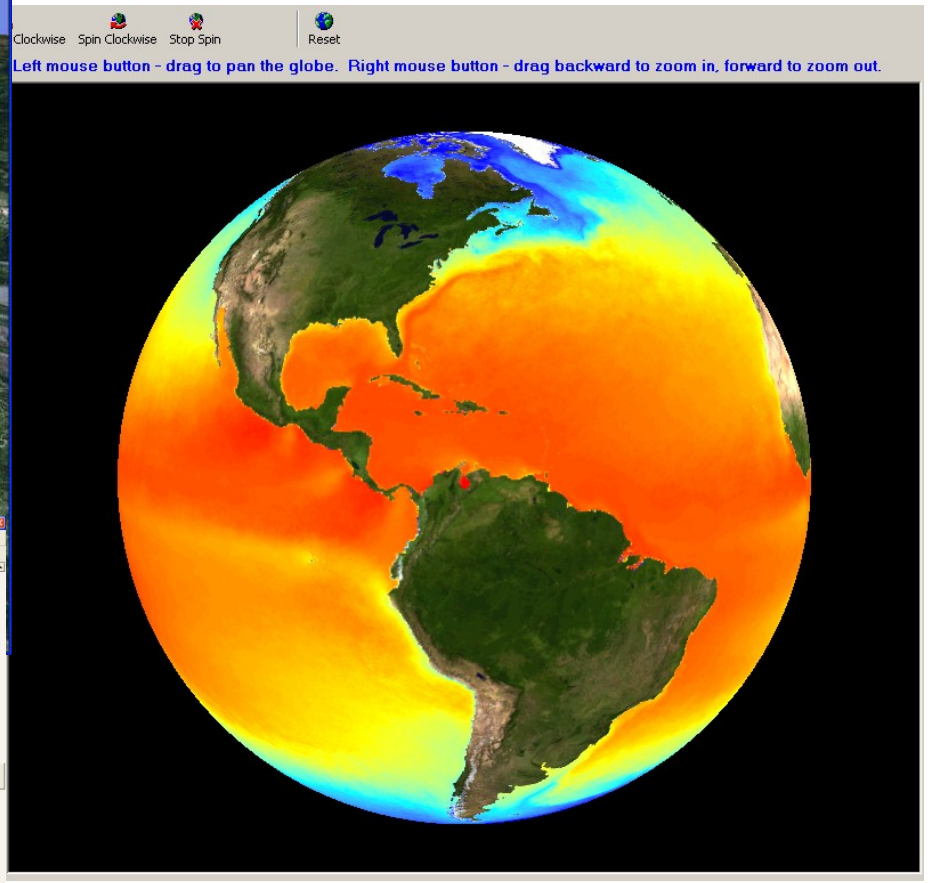
What is GIS?





ESRI

Geographical Information System

- **A set of tools for**
- **Collecting**
- **Storing**
- **Manipulating**
- **Retrieving**
- **Transforming and Display of Spatial Data from the Real World**

What is a GIS?

GEOGRAPHIC

implies that locations of the data items are known, or can be calculated, in terms of Geographic coordinates (Latitude, Longitude)

INFORMATION

implies that the data in a GIS are organized to yield useful knowledge, often as colored maps and images, but also as statistical graphics, tables, and various on-screen responses to interactive queries.

SYSTEM

implies that a GIS is made up from several inter-related and linked components with different functions. Thus, GIS have functional capabilities for data capture, input, manipulation, transformation, visualization, combinations, query, analysis, modelling and output.

What is GIS?

- GIS = Geographic Information System
  - Links databases and maps
  - Manages information about places
  - Helps answer questions such as:
    - Where is it?
    - What else is nearby?
    - Where is the highest concentration of ‘X’?
    - Where can I find things with characteristic ‘Y’?
    - Where is the closest ‘Z’ to my location?

What is GIS?

- A technology
  - hardware & software tools
- An information handling strategy
- The objective: to improve overall decision making

GIS: a formal definition

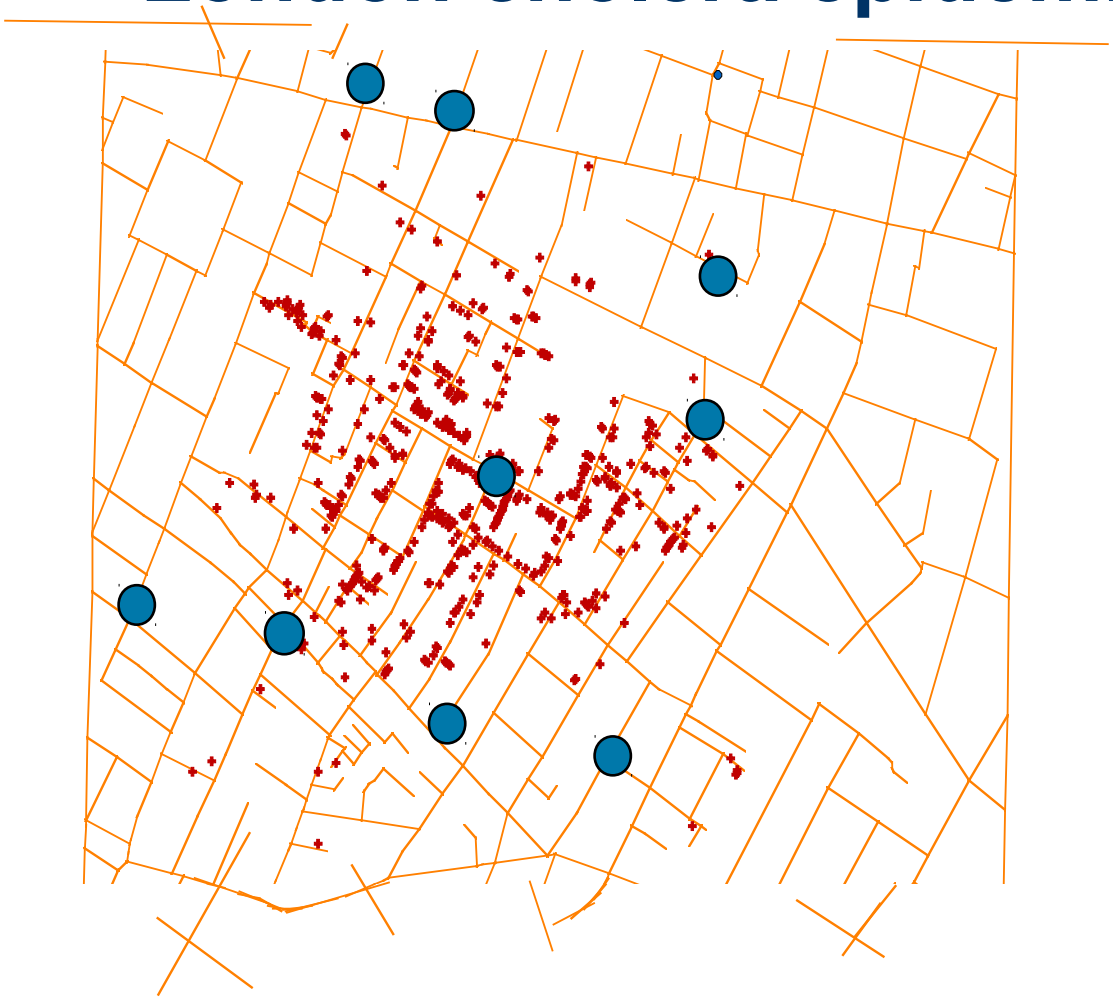
"A system for capturing, storing, checking, integrating, manipulating, analysing and displaying data which are spatially referenced to the Earth. This is normally considered to involve a spatially referenced computer database and appropriate applications software"

Why is GIS unique?

- GIS handles SPATIAL information
  - Information referenced by its location in space
- GIS makes connections between activities based on spatial proximity

GIS concepts

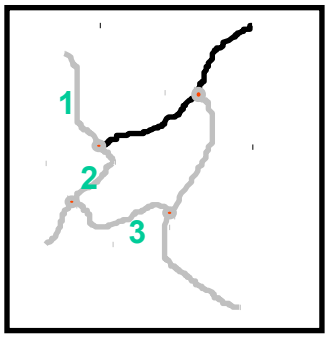
- London cholera epidemic 1854



GIS: historical background

This technology has developed from:

- Digital cartography and CAD
- Data Base Management Systems



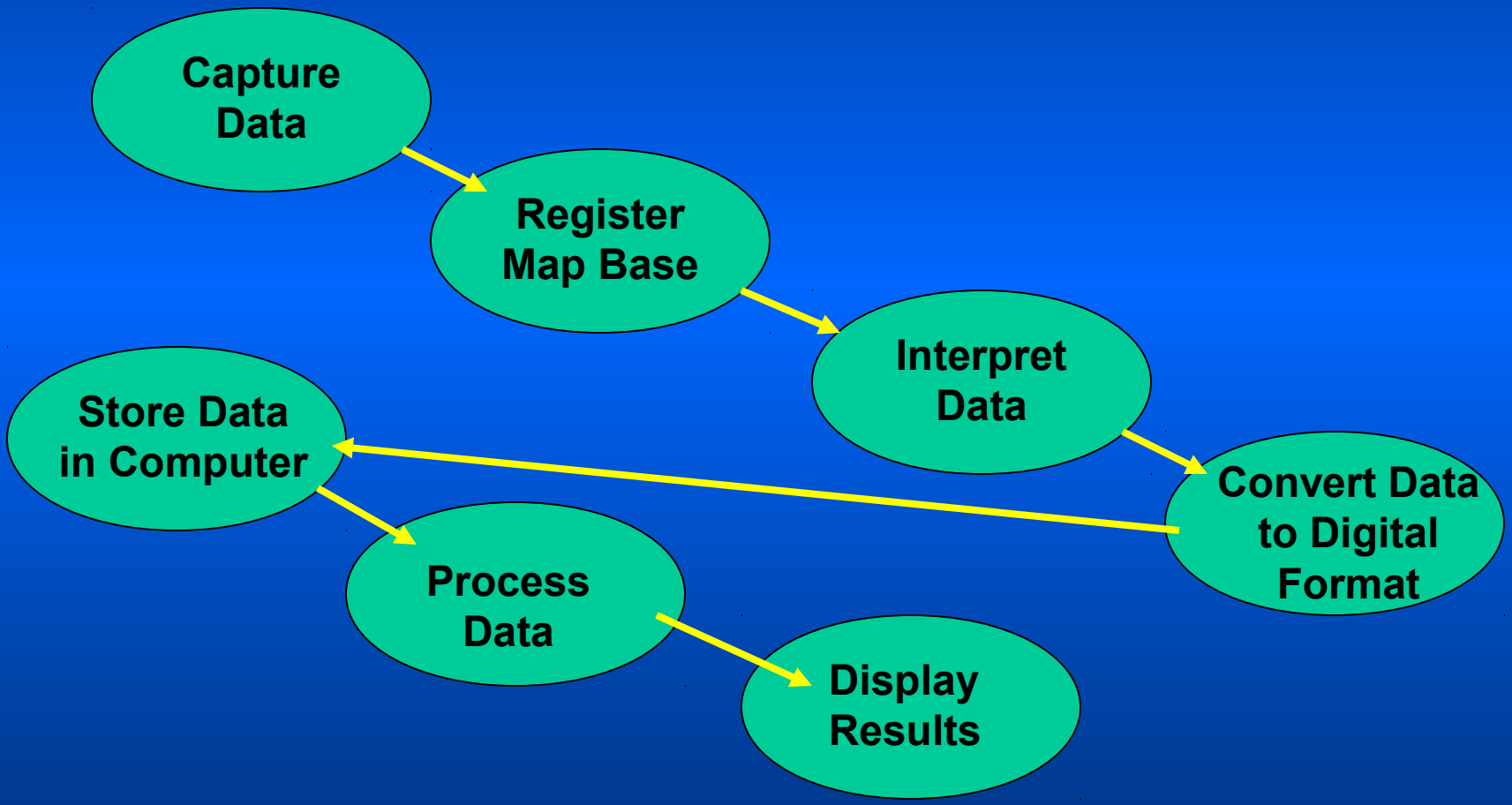
CAD System

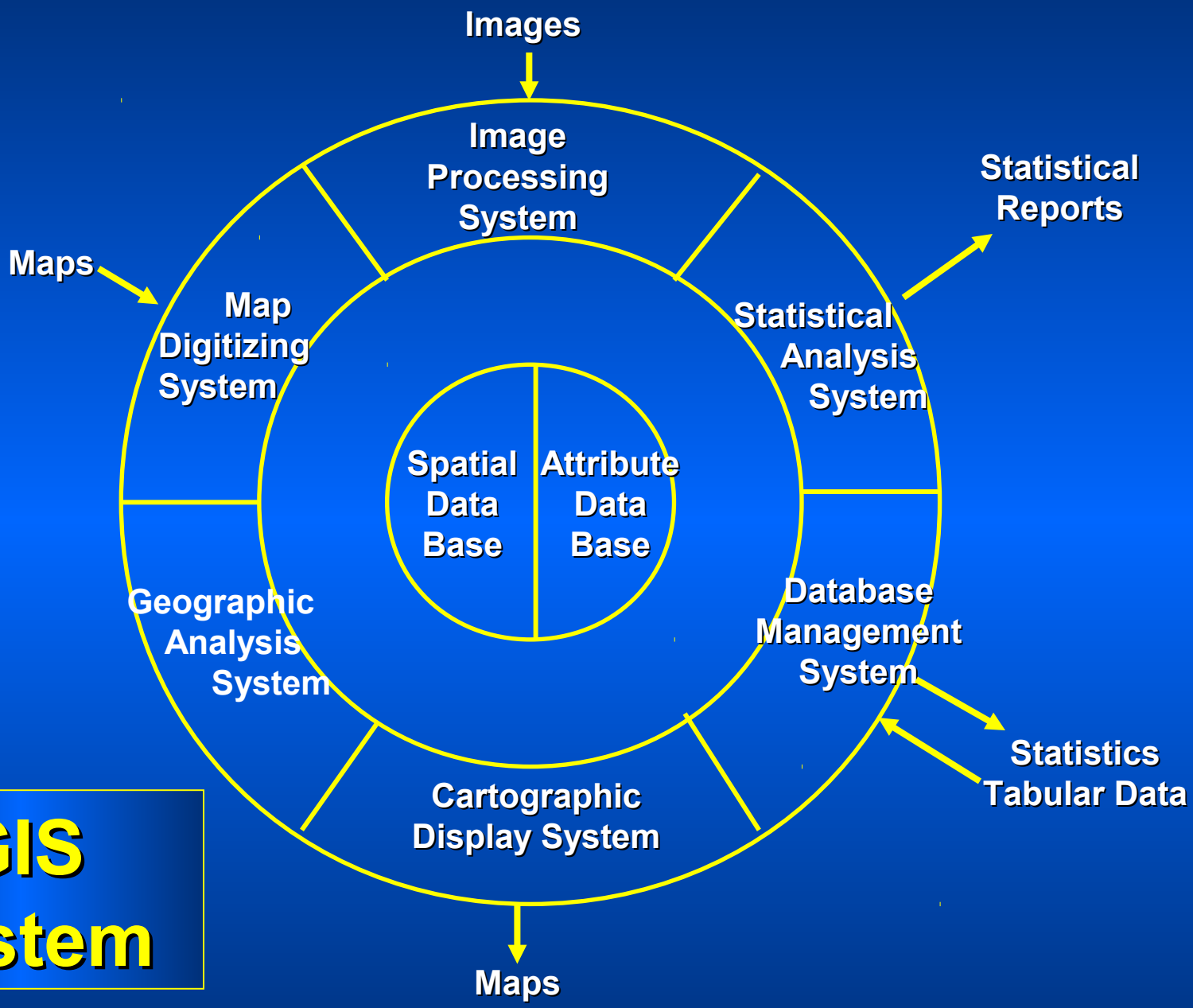
ID	X,Y
1	
2	
3	

ID	ATTRIB
1	
2	
3	

Data Base Management System

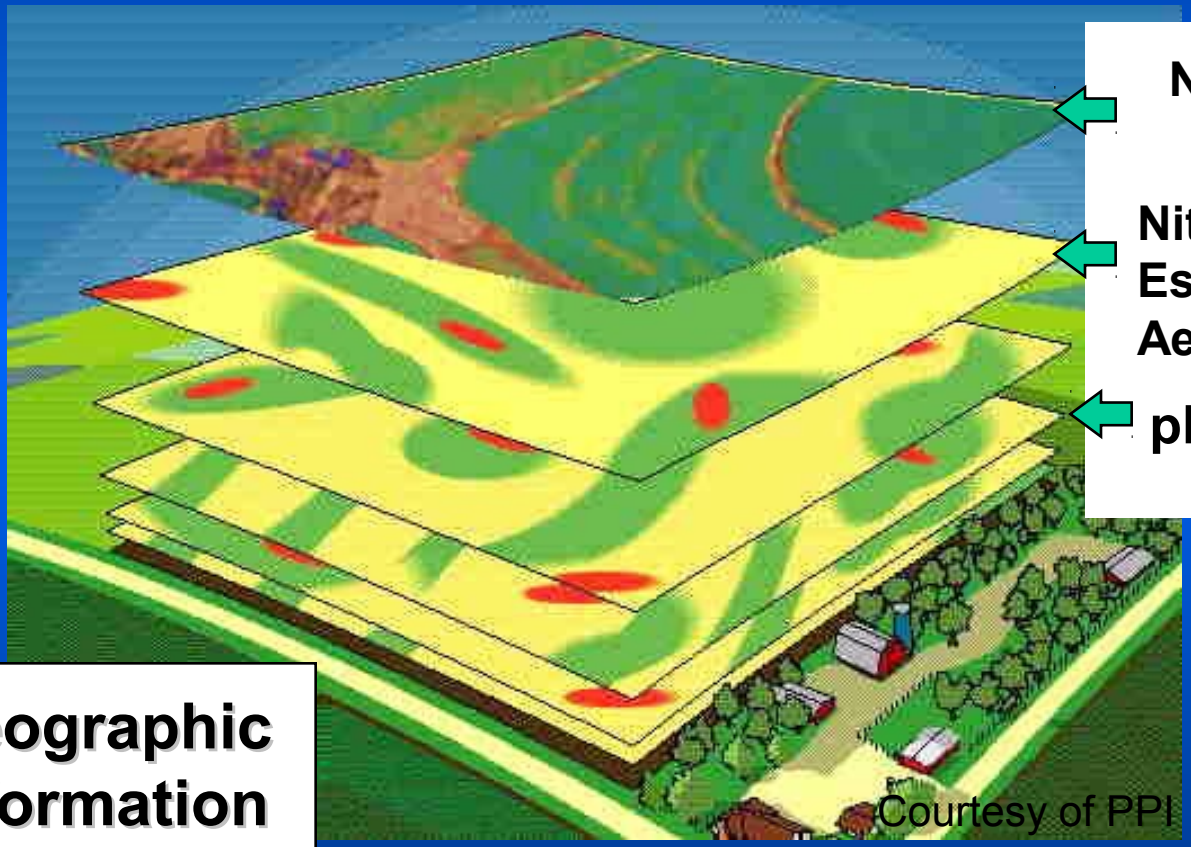
GIS Process


Capture Data
Register Map Base
Interpret Data
Convert Data to Digital Format
Store Data in Computer
Process Data
Display Results


Images
Image Processing System
Statistical Reports
Maps
Map Digitizing System
Statistical Analysis System
Spatial Data Base
Attribute Data Base
Geographic Analysis System
Database Management System
Statistics Tabular Data
Cartographic Display System
Maps

GIS System

GIS – Data Layers Stacking



NDVI From Aerial Image

Nitrogen Availability Estimate from Aerial Photo

pH Layer

Geographic Information System

GIS Areas

Geo Sciences

Civil Engineering

Transportation

Natural resources

Geology & Geophysics

Environment

Planning

Administration

Management

Business

Remote Sensing

Image processing

Urban & Rural Development

Floods , Disasters

Oil exploration

Mines

Surveys

Watershed management

Tourism

Communications

Softwares

GIS

- ARC INFO
- ArcGIS
- MapInfo
- GRASS
- Geomedia
- Geoconcept
- WIN GIS
- Microstation
- AutoCAD

Digital Image Processing

- ERDAS Imagine
- ER Mapper
- ILWIS
- ENVI
- PCI Geomatica
- ArcView image analysis
- TNTMIPS
- Ecognition

Major Services in GIS

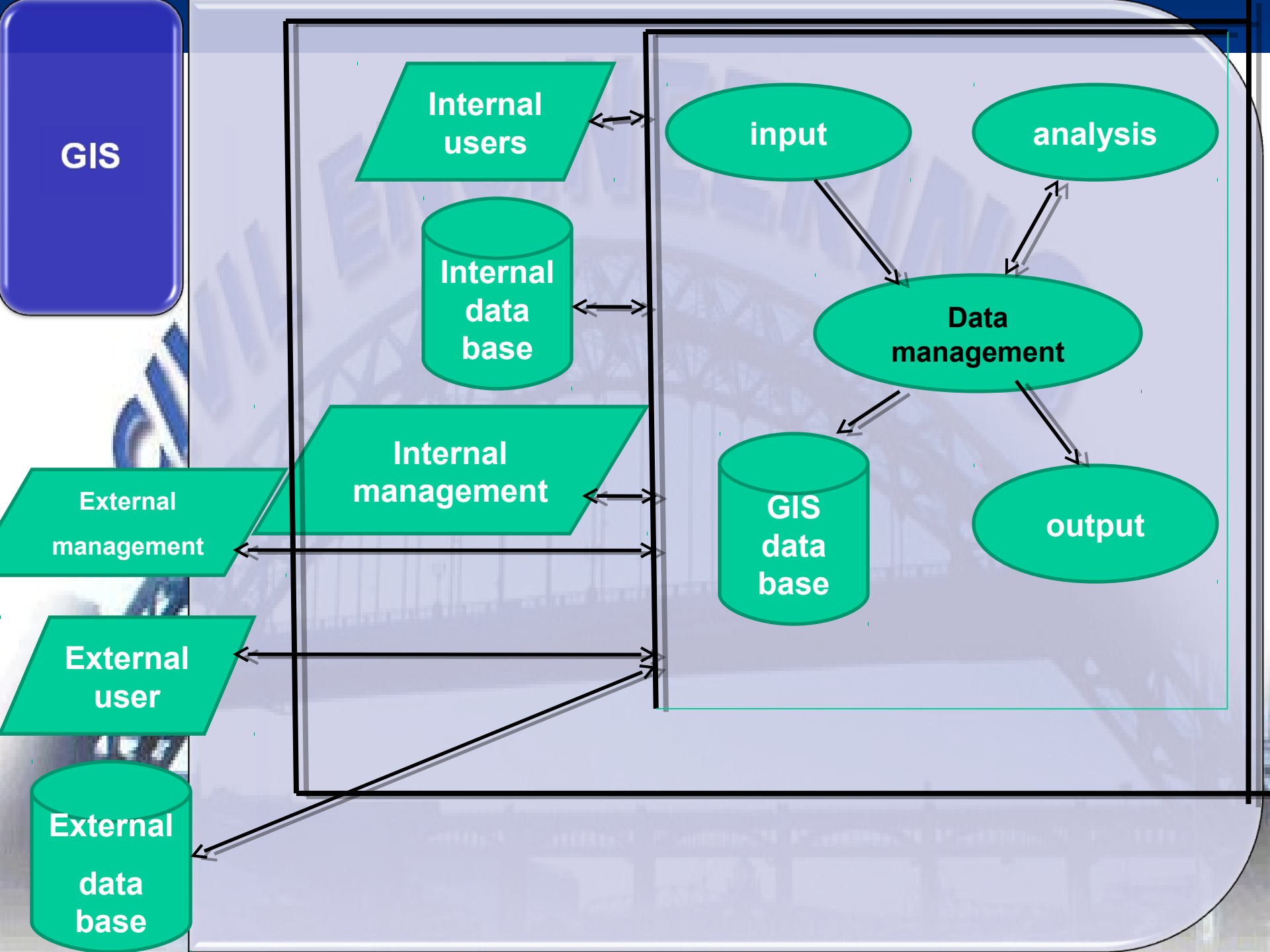
- GIS Application Software development
- Remote Sensing Application Projects
- Thematic Mapping
- Digital Image Processing Services
- Engineering Application Software solutions
- Data Conversions
- Complete GIS Implementation
- Consultation

GIS

- **COMPONENTS OF GIS:**

- 1.Computer system (hardware):
  - It includes – CPU , VDU , keyboard , mouse , plotter , printer , CD/DVD drive etc . – to store , process , and present spatial data

- 2.Software :
  - Includes software like – Arc GIS, Map info , Geometrica , Autodesk Map – to perform GIS operation


GIS
Internal users
input
analysis
Internal data base
Data management
Internal management
External management
GIS data base
output
External user
External data base

GIS

- 3.Data :
  - Geographical data in – form of - hard copy map , digital map ,aerial photos , satellite images , statistical tables , other documents - used for GIS operations
- 4.Procedure and Analysis:
  - To complete task – procedures are performed using – hardware and software
- 5.Expert and skilled personnel:
  - Experts with knowledge area required to apply GIS properly
  - Different types of users are using GIS at different level

What are the main functions of a GIS ?

- Data capture : digitising, scanning, importing, manual data entry
- Data storage and management : database design, data integration
- Data manipulation/editing : cleaning and editing of data, dissolving boundaries, layering, georeferencing
- Data display : display of spatial and attribute

- Data Manipulation and analysis
  - Spatial analysis
    - Simple searches
    - Network analysis
    - Buffering
    - Corridor analysis
    - Proximity analysis
    - Boolean analysis (union, intersection, etc.,)
    - etc.,

- Presentation/ Visualisation
  - Map making
  - Charts
  - Tables
  - 3D Views
  - Generation animations
  - etc.,

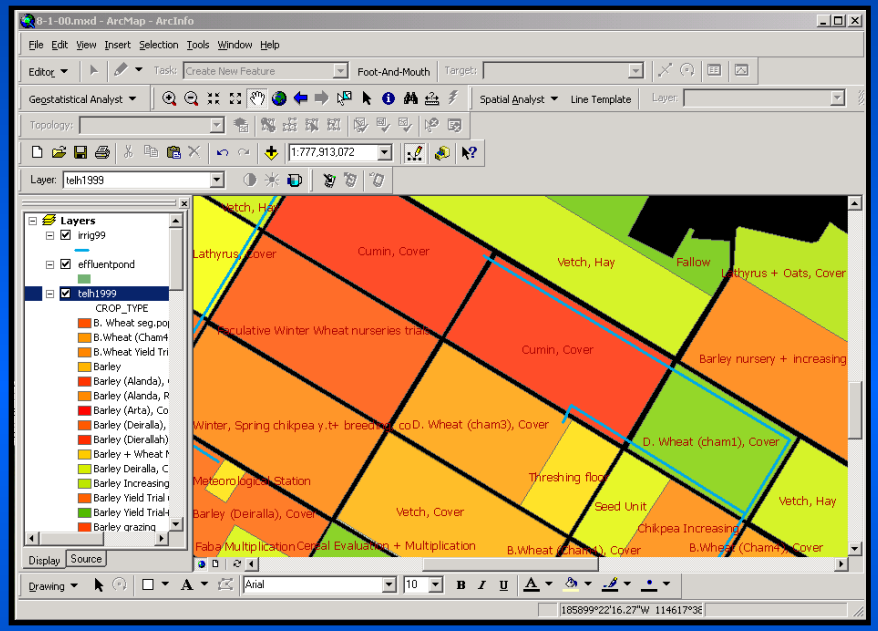
Application of GIS

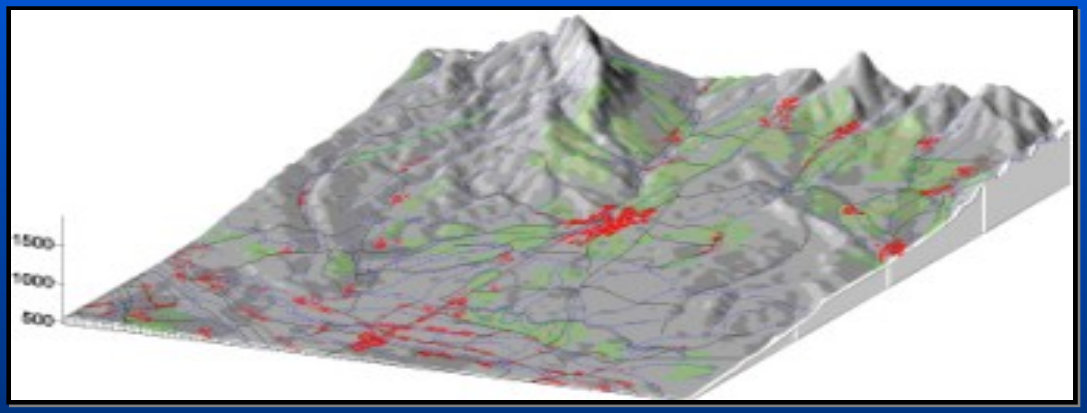
- **GIS used in multiple disciplines:**

Agriculture
Archaeology
Architecture/Landscape Arch.
Business
Computer Science
Environmental Science
Engineering
Journalism
Military Science
Natural Resource Management
Geography
Geology
Meteorology
Oceanography
Law Enforcement
Public Health
History
Sociology
Urban/Regional Planning

Agriculture

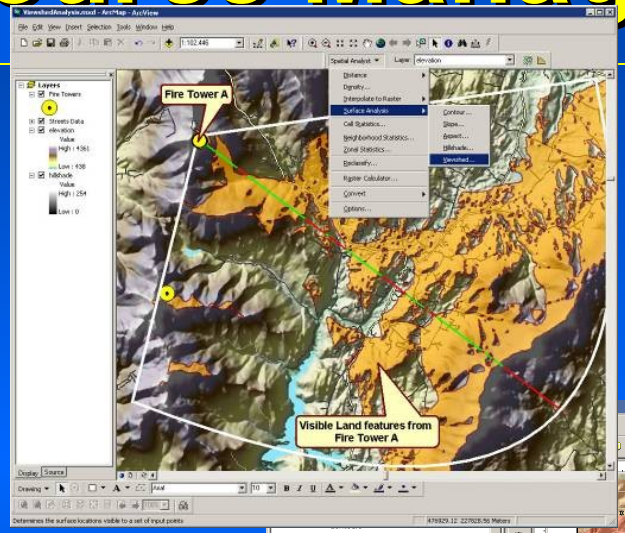
- Farm management
- Pest/Disease tracking
- Crop monitoring
- Yield prediction
- Soil analysis

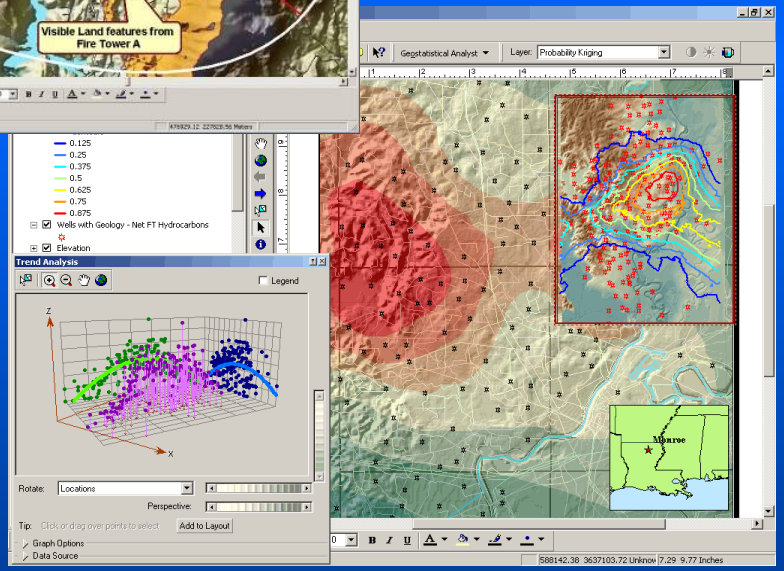


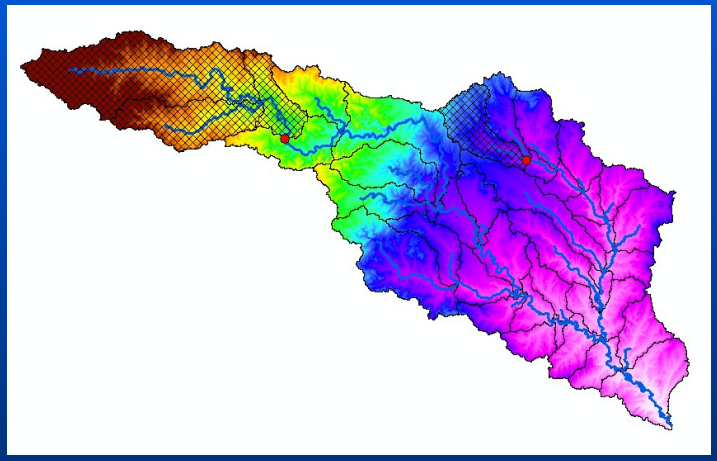


Natural Resource Management

- Forestry
- Ecology
- Mining
- Petroleum
- Water Resources

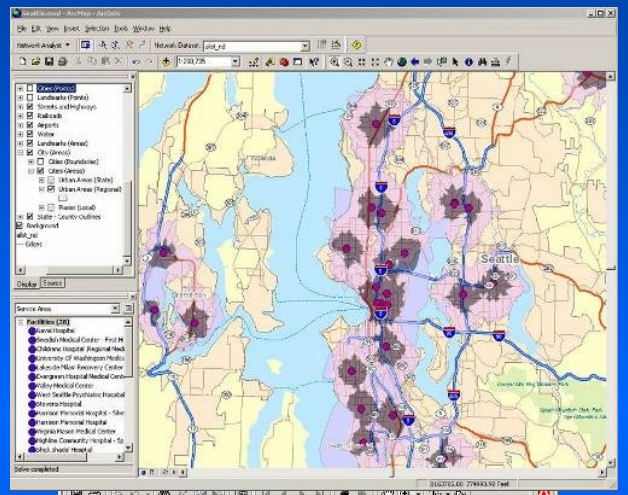


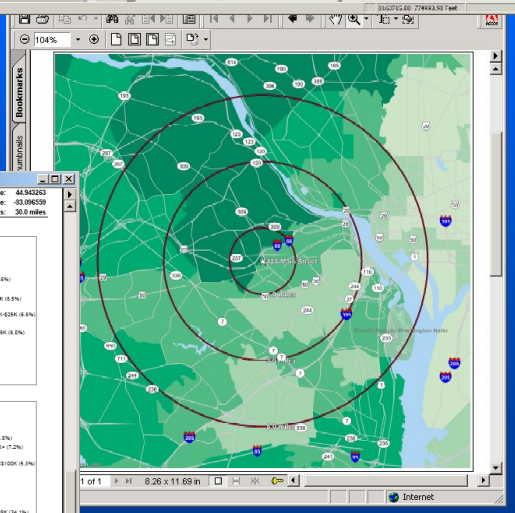


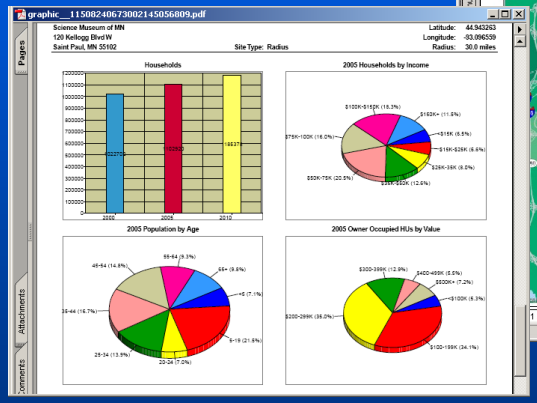


Planning and Economic Development

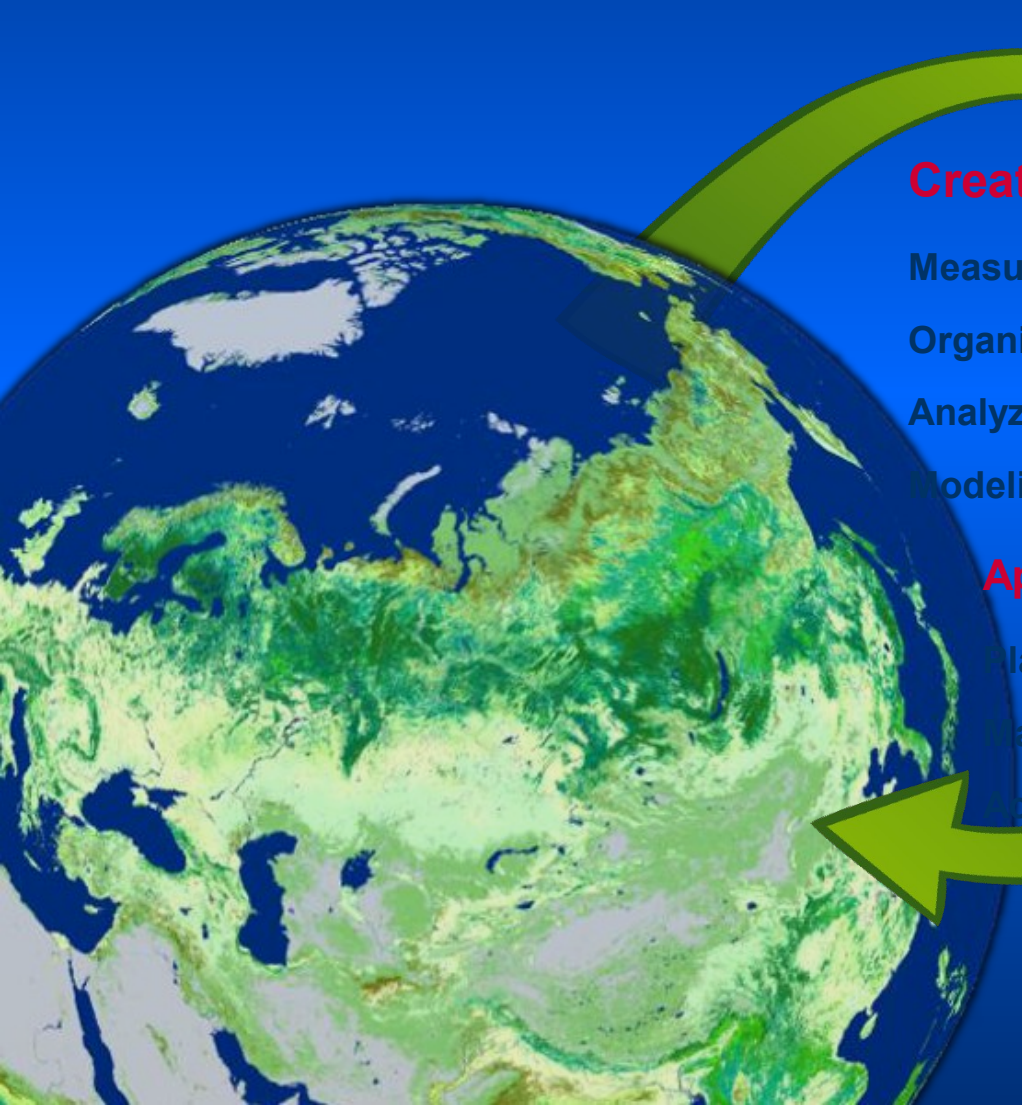
- Land Use/Zoning
- Emergency Preparedness
- Population Forecast
- Market Analysis
- Property Tax Assessment
- Transportation



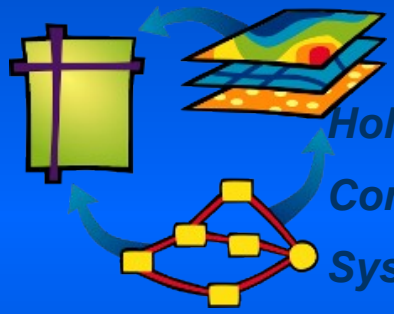




GIS: A Framework for Understanding and Managing Our Earth



Geographic Knowledge



Holistic

Comprehensive

Systematic

Analytic

Visual

Creating

Measuring

Organizing

Analyzing

Modeling

Applying

Planning

Managing

Acting

Geography matters

Today's challenges require geographic approach

- Climate Change
- Urban Growth
- Sustainable Agriculture
- Water Quality and Availability
- International and National Security
- Energy
- Epidemiology/Disease Tracking
- Natural Hazards: Seismicity, Weather Events

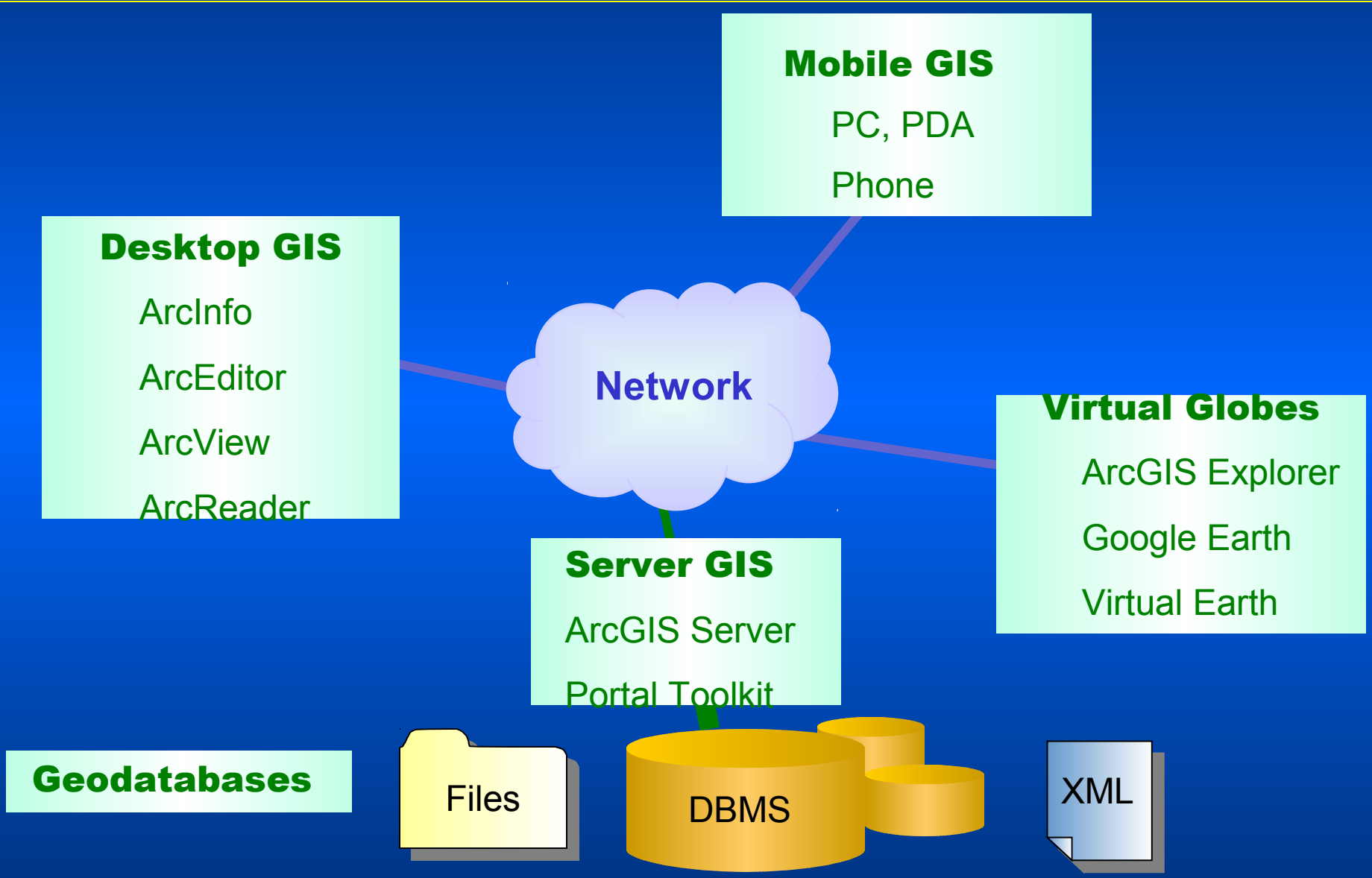
GIS as Infrastructure

- Because GIS is used in many departments, coordination is needed
  - Software licensing
  - Instruction
  - Data

GIS as infrastructure

- Data is greatest expense
  - Previously: Data scattered in multiple departments, not coordinated
  - Future: Data accessible anywhere, GIS portal and Web services facilitate sharing
- Libraries / Data Centers key
  - GIS data has unique characteristics

GIS as infrastructure



Civil Engineering Applications

- Transportation
- Watershed analysis
- Remote sensing

Location-Allocation

- Finding a subset of locations from a set of potential or candidate locations that best serve some existing demand so as minimize some cost
- *Locate* sites to best serve *allocated* demand
- Application areas are warehouse location, fast food locations, fire stations, schools

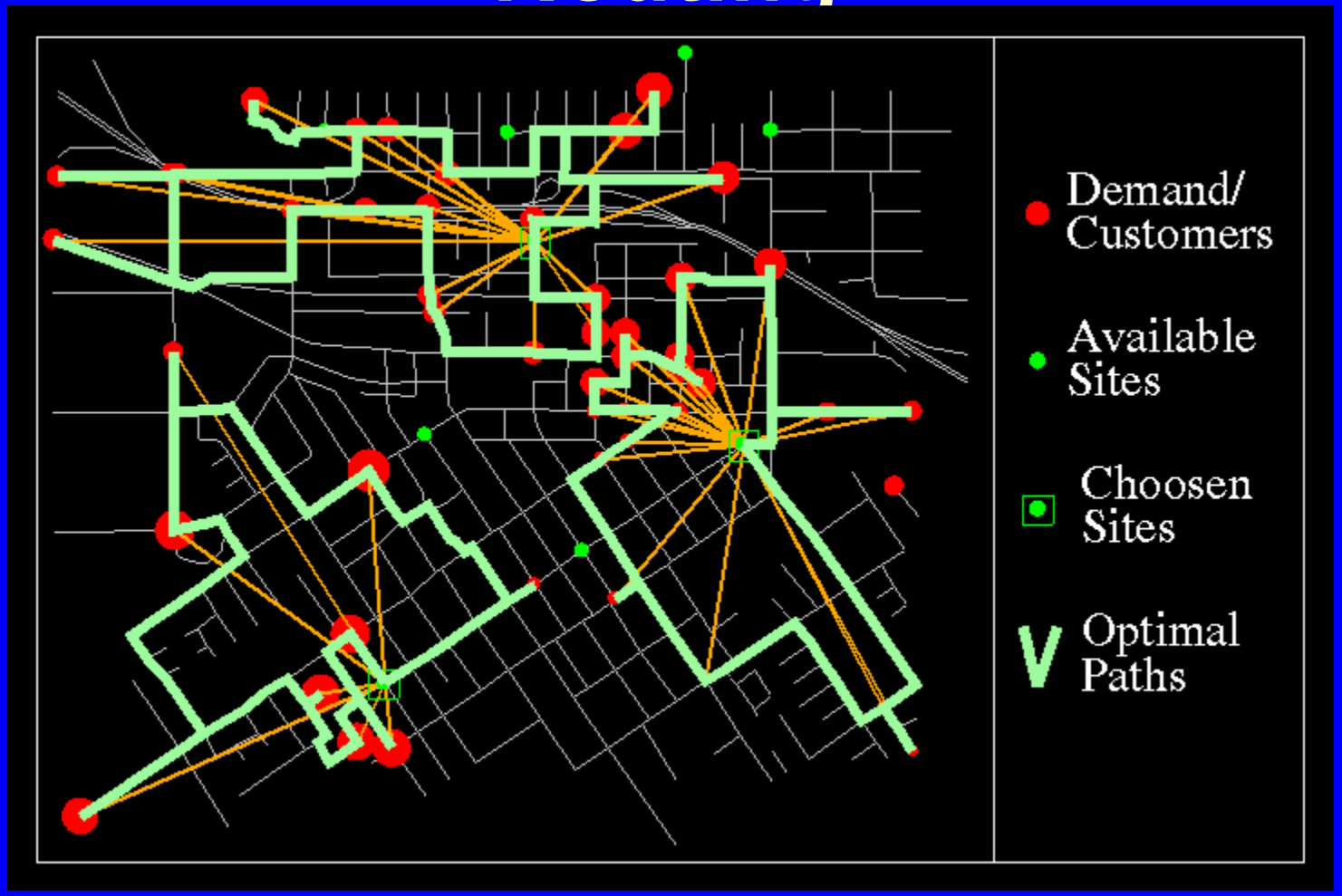
Location-Allocation Inputs

- Customer or demand locations
- Potential site locations and/or existing facilities
- Street network or Euclidean distance
- The problem to solve

Location-Allocation Outputs

- The best sites
- The optimal allocation of demand locations to those sites
- Lots of statistical and summary information about that particular allocation

Vehicle Routing



(From , ESRI)

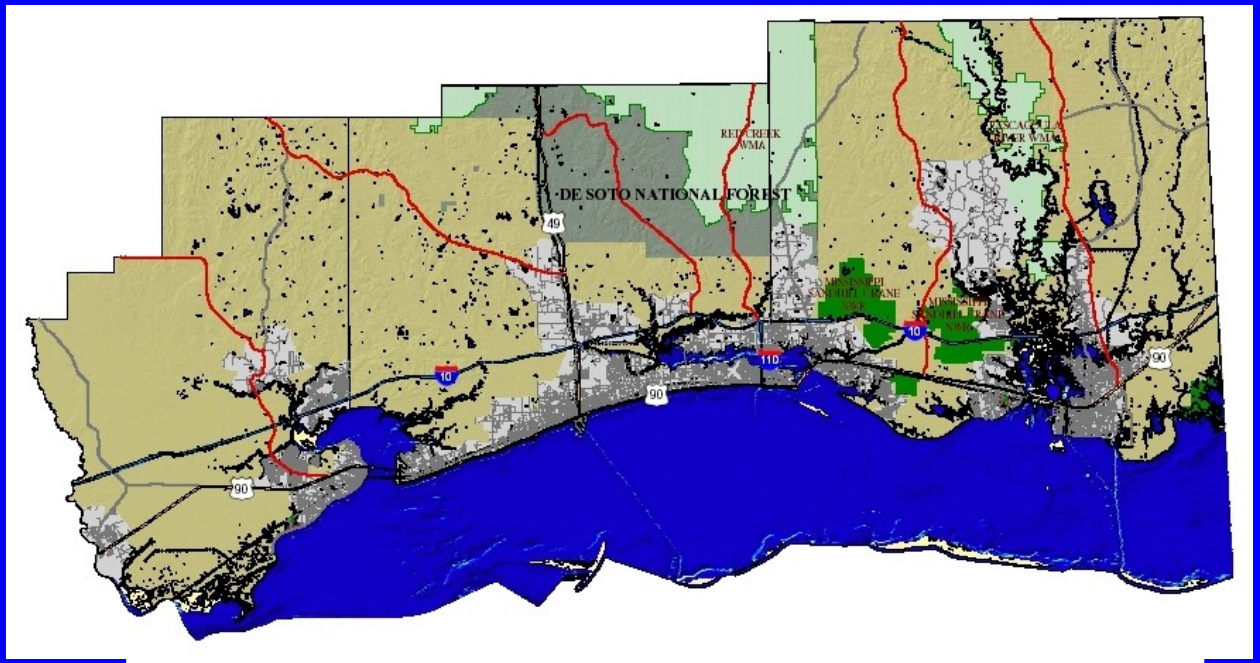
Synergy between spatial data and analysis

- Imagine you are a national retailer
- You need warehouses to supply your outlets
- You do not wish the warehouses to be more than 1000 km from any outlet

(Example from, ESRI)

Other Transportation Applications

- **Planning & locating new roadway corridors**



(from NCRST-E)

Transportation – Emergency Operations

- Transportation maps are critical
- Disaster response plans can be developed
- Outside computer models used for advance warnings
- Land use maps enhance emergency operations

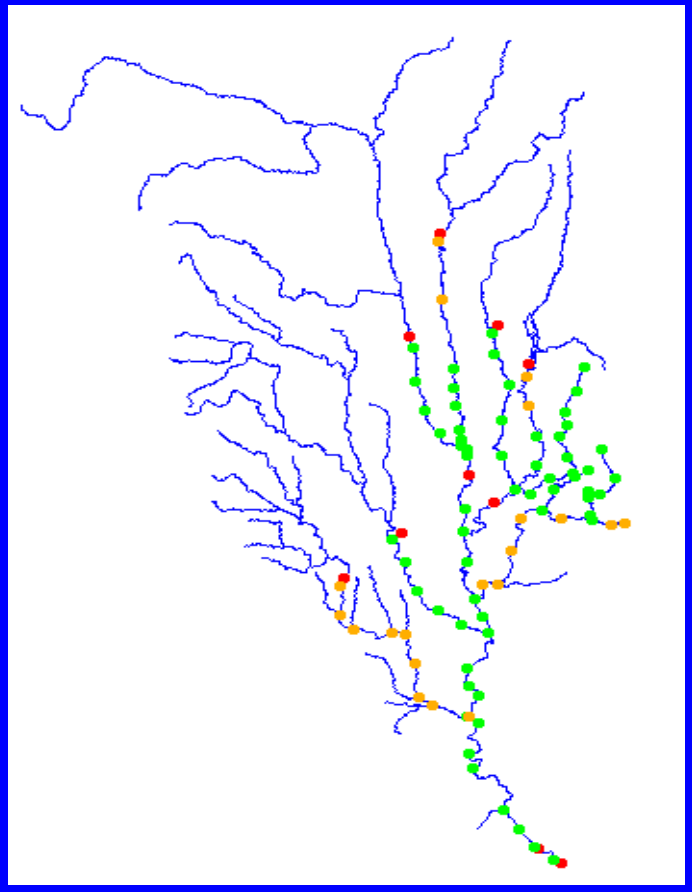
Watershed Characterization

- Relate physical characteristics to water quality & quantity
- Data – land use & land cover, geology, soils, hydrography & topography – related to hydrological properties

Watershed Applications

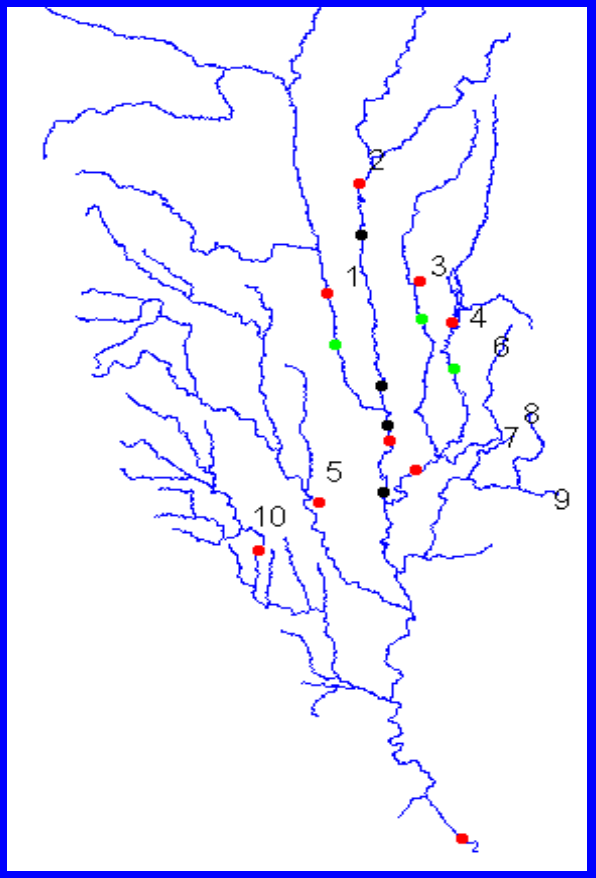
- Estimate the magnitude of high-flow events, the probability of low-flow events
- Determine flood zones
- Identify high-potential erosion areas
- For example, BASINS, HEC-RAS, MIKE11 models integrated with GIS

Cross sections

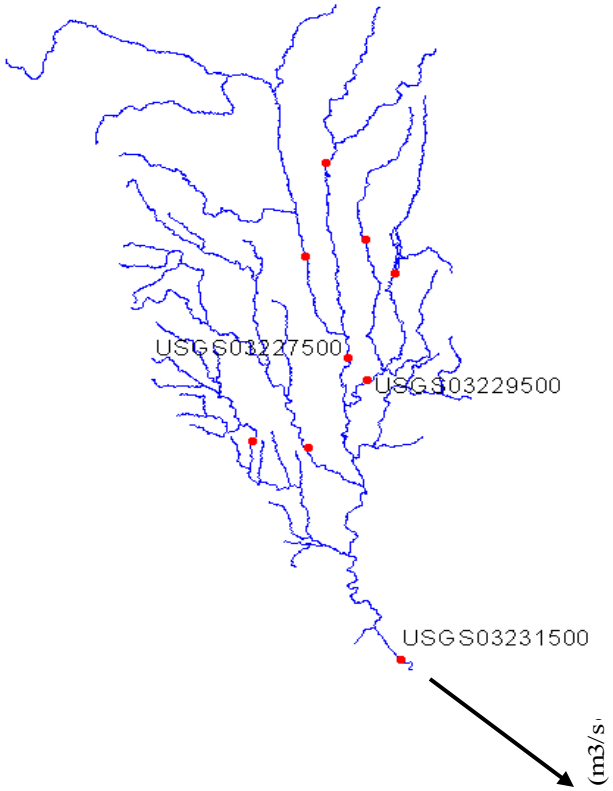


- cross sections
- assumed cross sections
- boundary conditions

Boundary conditions



- gaging station
- water treatment plant
- wastewater treatment plant


USGS03227500
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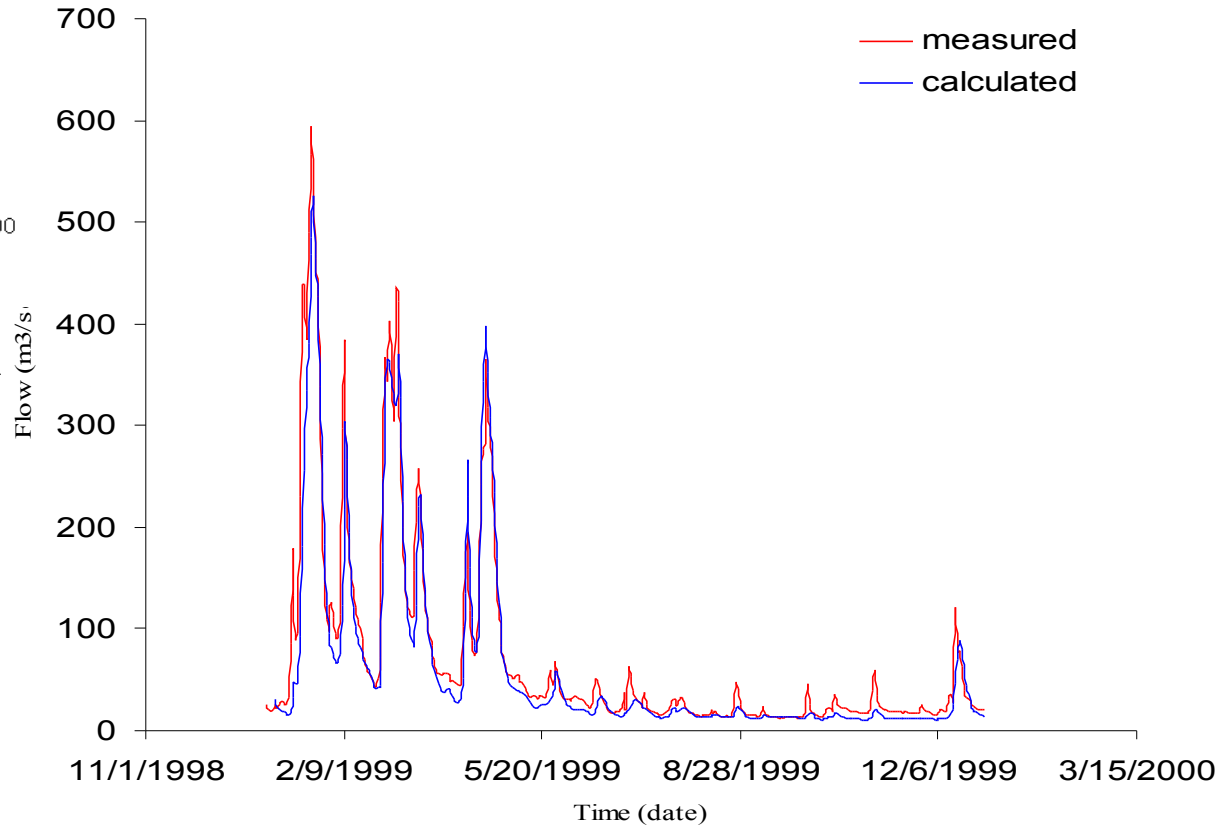
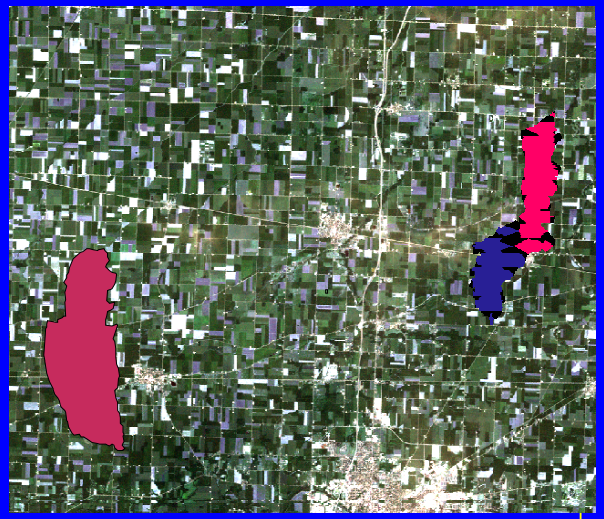

700
600
500
400
300
200
100
0
Flow (m3/s
11/1/1998
2/9/1999
5/20/1999
8/28/1999
12/6/1999
3/15/2000
Time (date)
measured
calculated

03231500

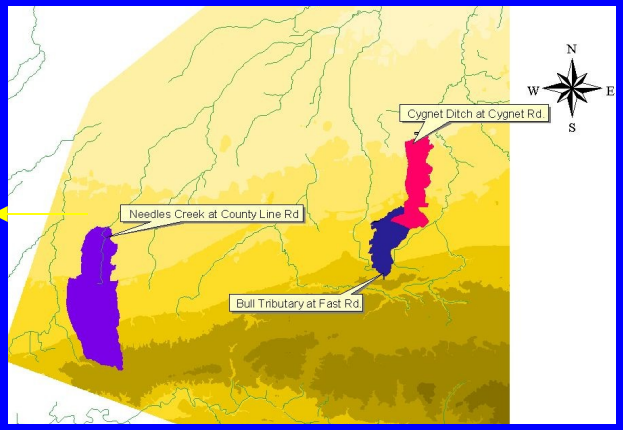
Slope Stability Analysis

- **Derive physical characteristics**
  - area, perimeter, flow path length, maximum width, average closing angle, watershed topology, soil data
- **Derive watershed characteristics**
  - watershed boundaries, drainage network, slope & aspect maps

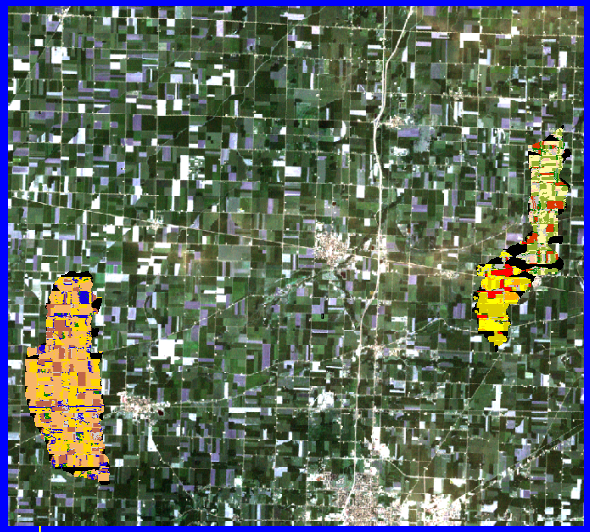
Portage River Basin, Ohio



Watersheds



DEM with drainage network



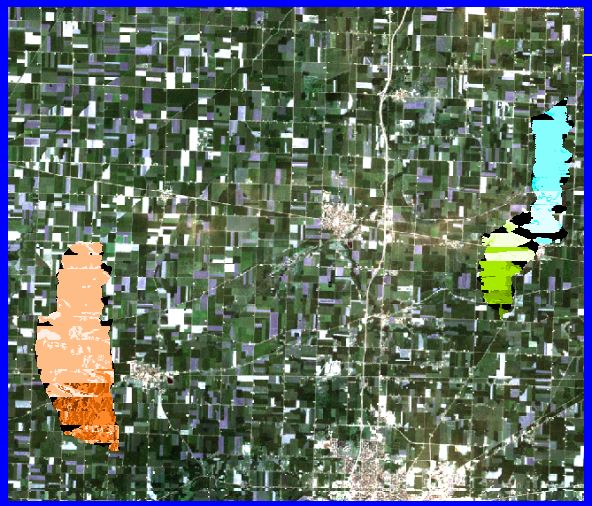
Land use

Hydrologic models

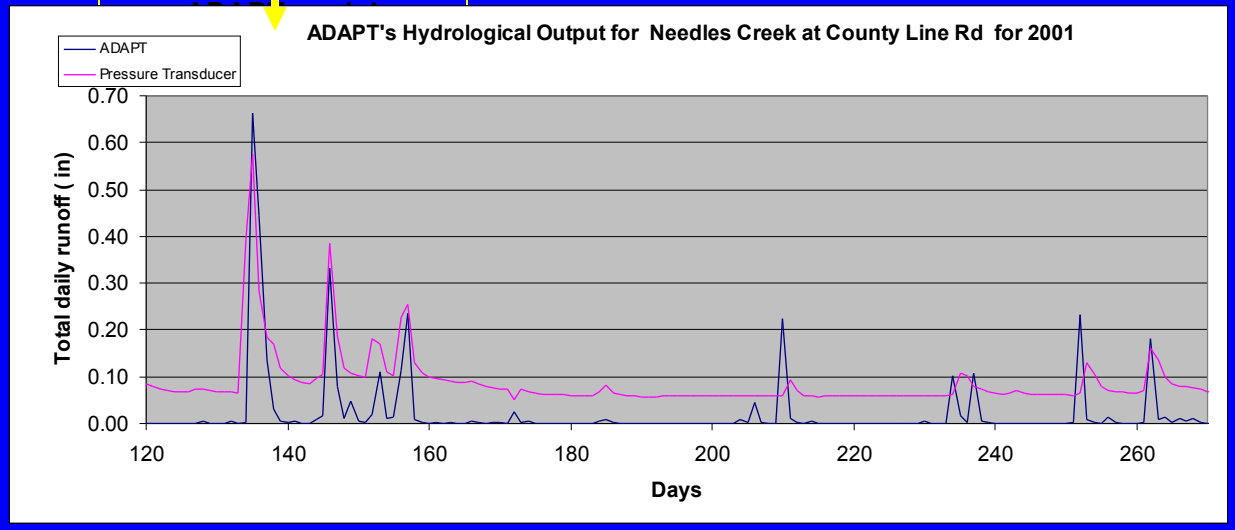
USGS empirical method

TR55

Area- Discharge method

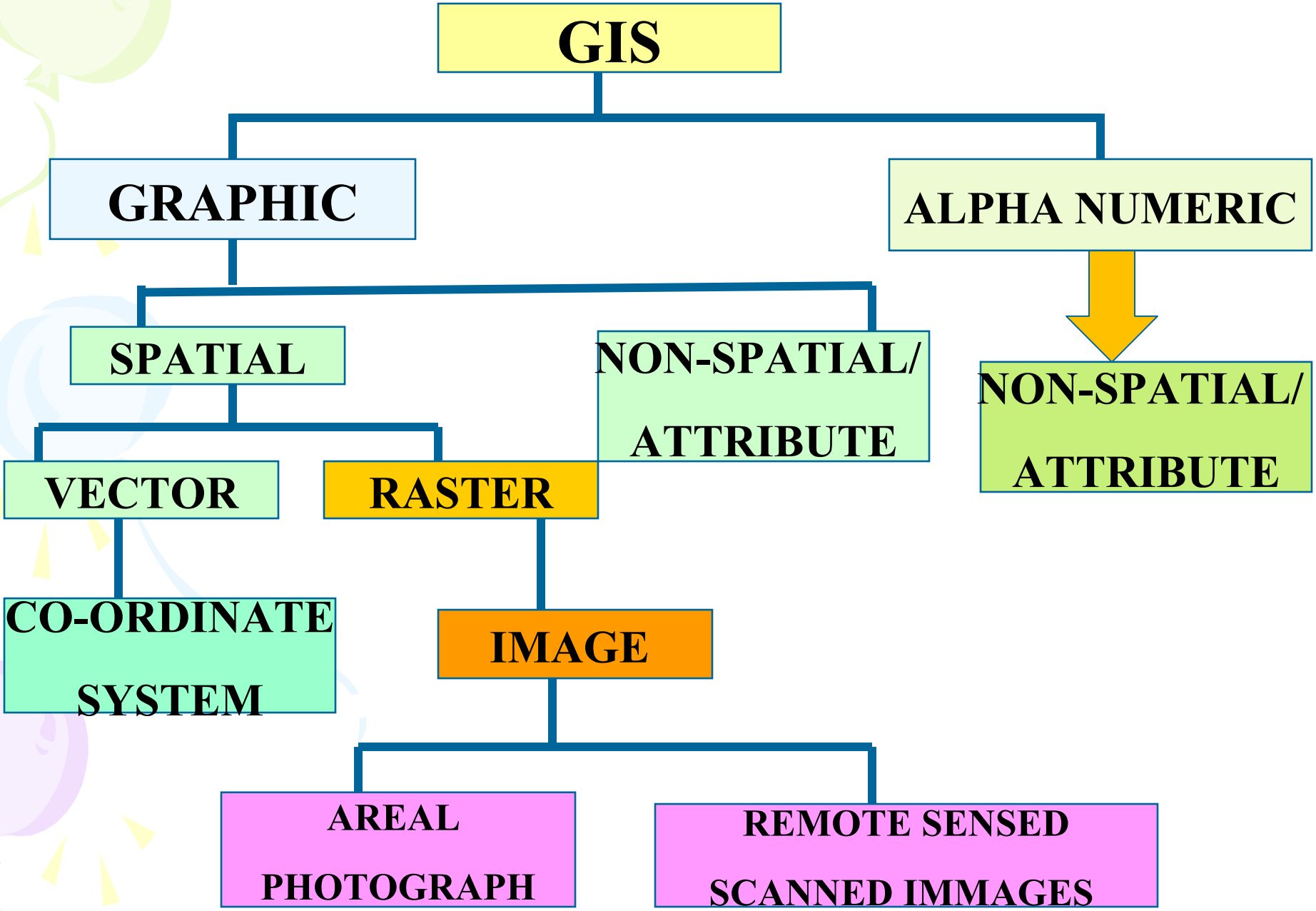


Soils types



GIS DATA AND SOURCES

Data Structure



Maps And Map Elements

- Maps are graphic representation of our perception of the world around us. They represent cartographic interpretation and simplification of reality.

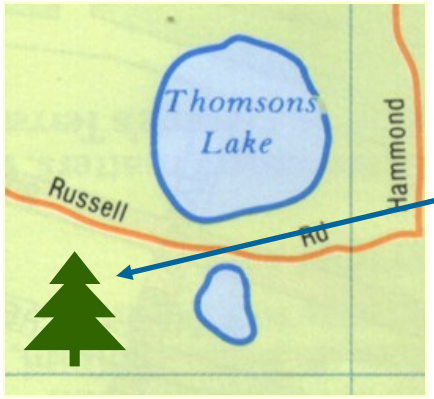
- Maps provide two types of information
  - Locational information
  - Spatial Relationships

Maps contains features such as……..
Point, Line, Area and Surface

- Maps contain POINT features, LINE features and AREA features
- Point Features :- wells, control points, sample sites, fire stations
- Line Features :- roads, hydro lines, rivers, contour lines,
- Area Features:-urban areas, water bodies, soil/rock units, forest areas

Point Features

- Spatially distributed entities, activities or events
- Points have a single geographic coordinate such as:
  - Tree
  - Traffic accident
  - Lamp post

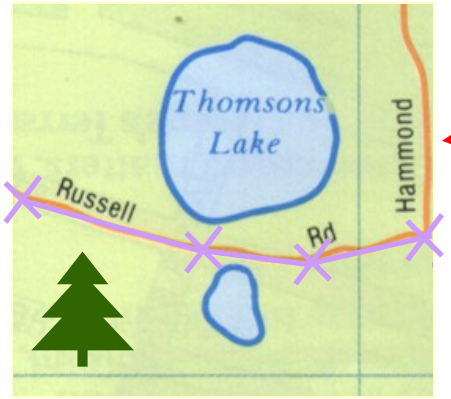


Points :

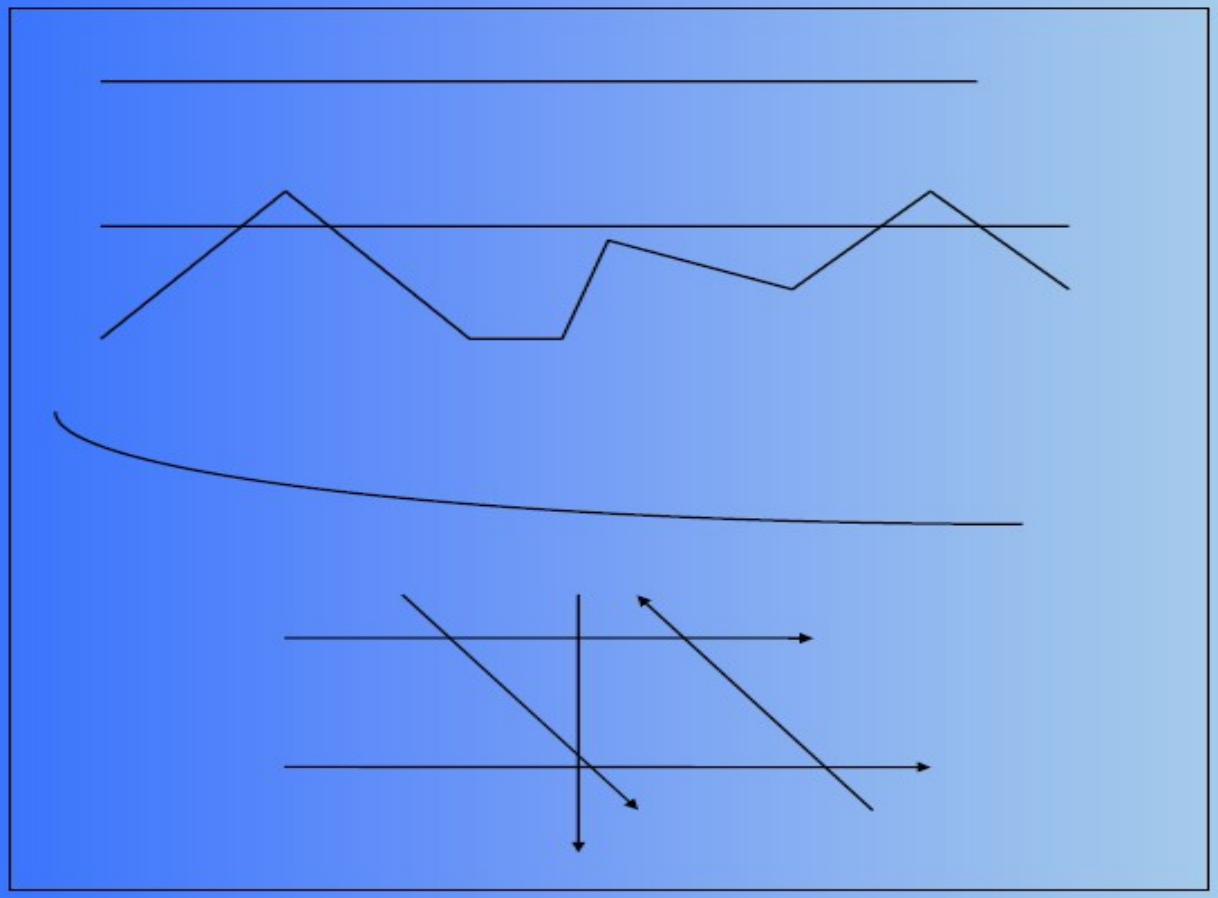
e.g. wells, sample sites, huts, schools, clinics

Line Features

- Spatially distributed entities, activities or events
- Lines (Arcs) are a series of geographic coordinates joined to form a line such as:
  - Road
  - Stream
  - Railway



Lines :



Simple

Complex

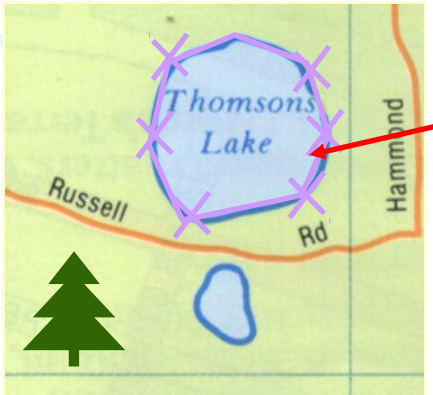
Curves

Networks

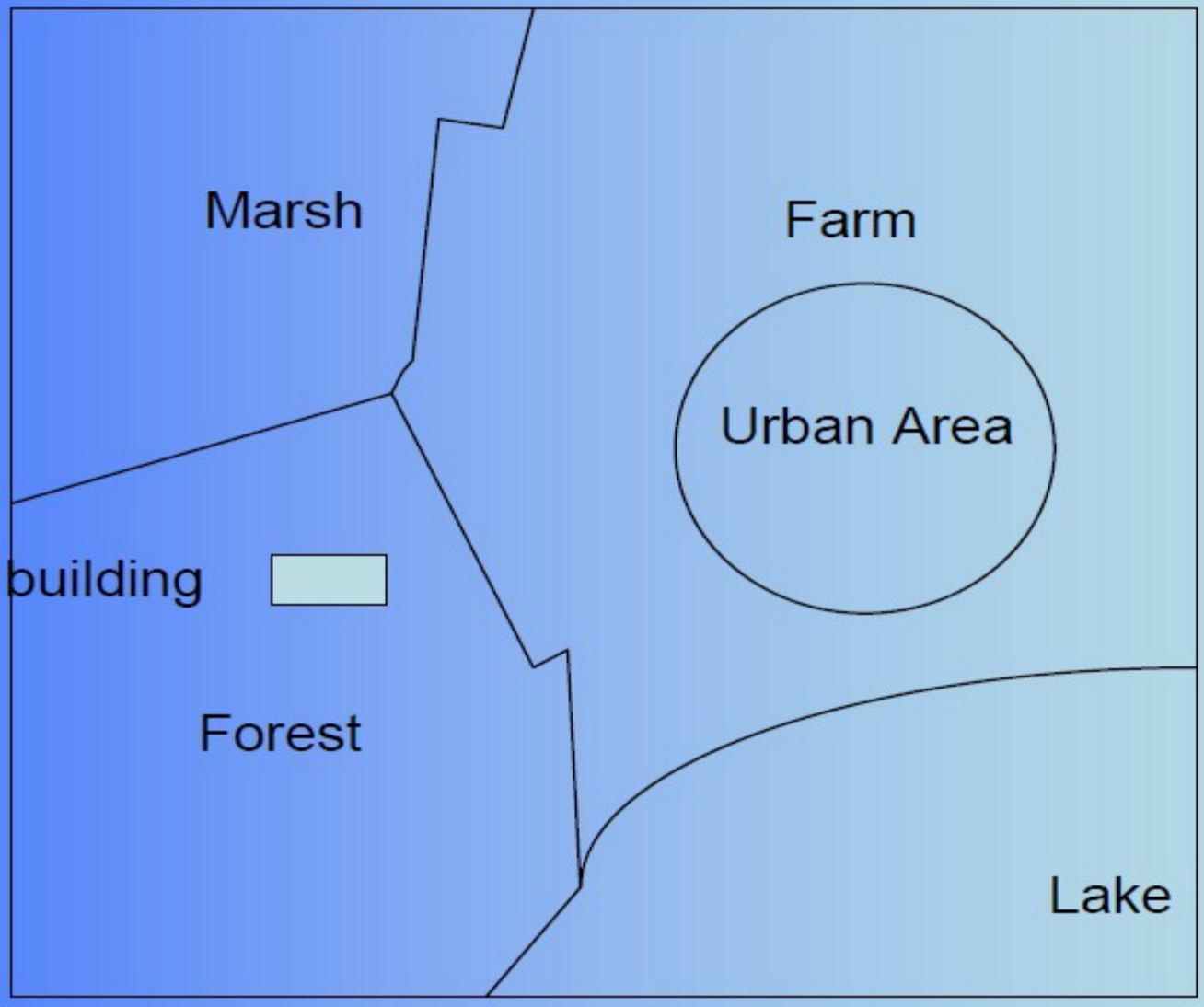
e.g. roads, rivers, powerlines, faults

Area Features

- Spatially distributed entities, activities or
- events
- Areas (Polygons) are a series of geographic coordinates joined together to form a boundary such as:
  - Lake
  - Soil types



Polygons



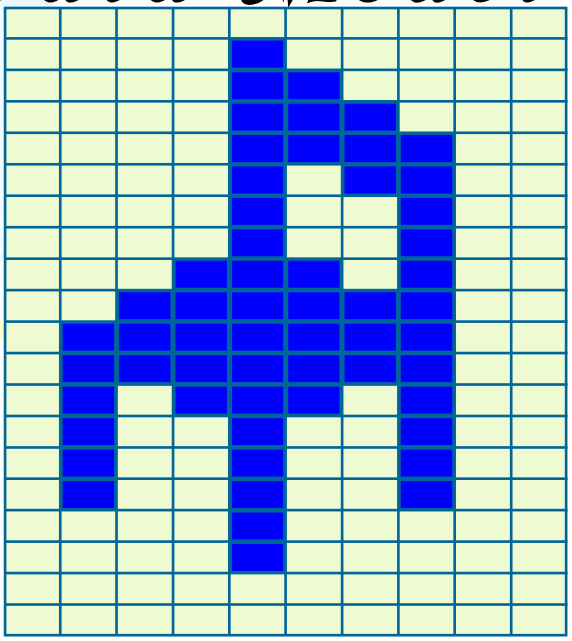
GIS Data Formats

- There are two formats used by GIS systems to store and retrieve geographical data:
  - *Raster*
  - *Vector*

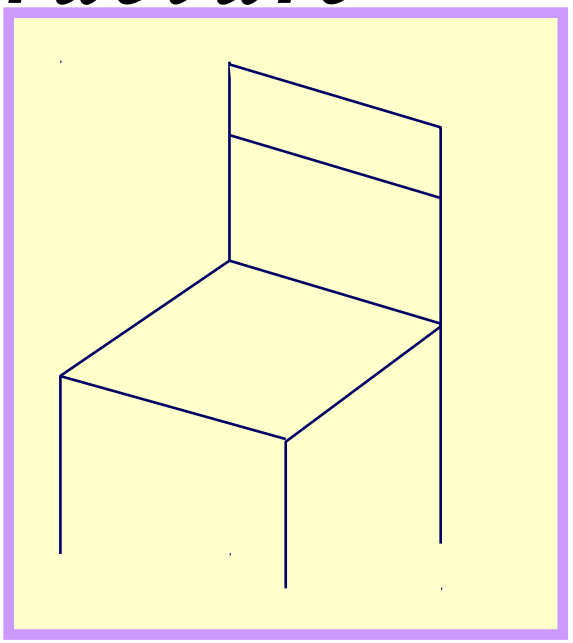
SPATIAL DATA

- Raster
- Vector

Data Model And Structure



RASTER MODEL



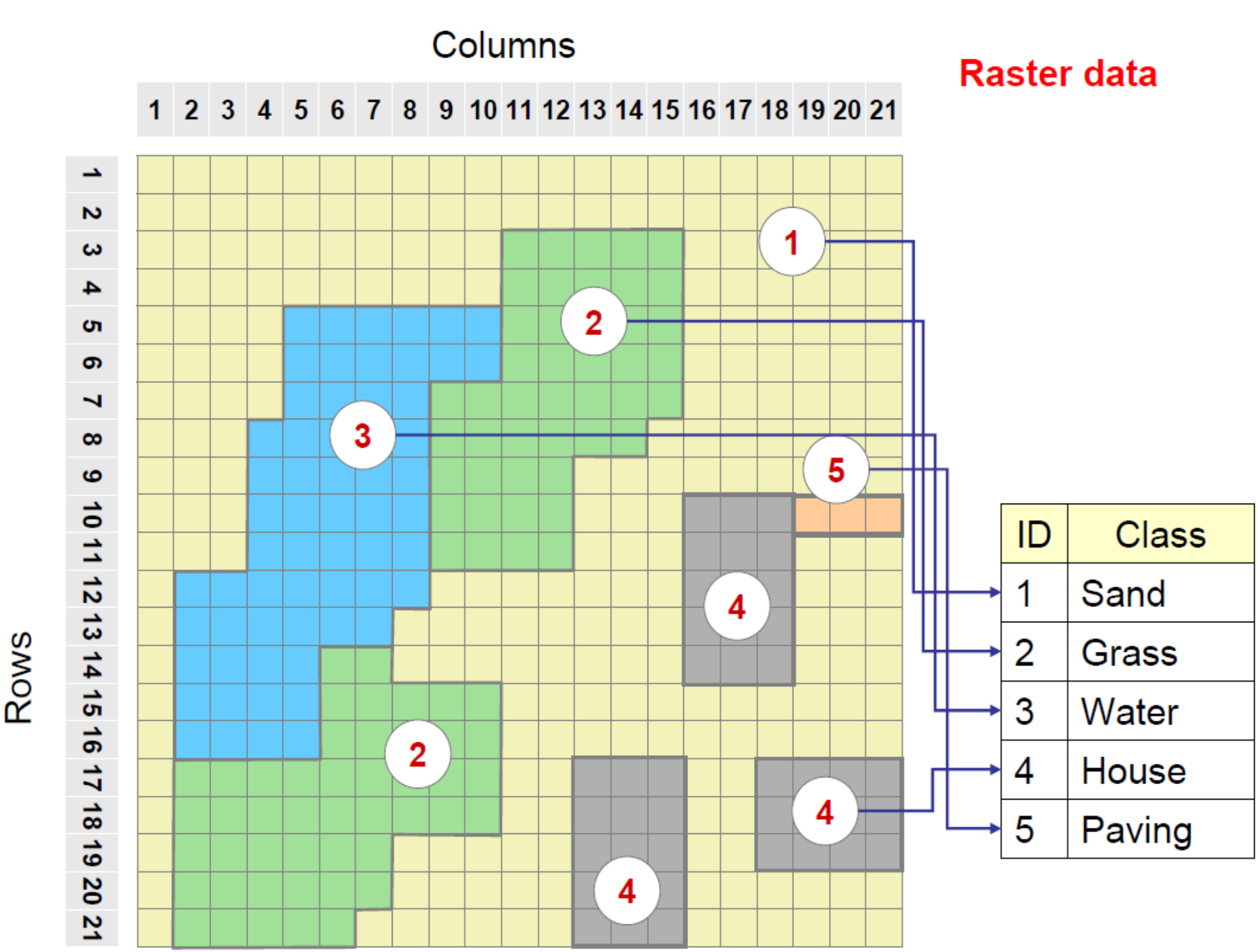
VECTOR MODEL

Raster Format

- Data are divided into cell, pixels, or elements
- Cells are organized in arrays
- Each cell has a single value
- Row and Column Numbers are used to identify the location of the cell within the array.
- Perhaps the most common example of raster data is a digital image.

Raster Data

- A grid (or raster) system stores data as a string of characters in which each character represents a location.
- The basic data unit is a cell or Pixel Each cell/Pixel is assigned only one value
- An array of Pixels form the entity-Point, Line, Area and surface
- The shape and size of the array determines the basic Resolution
- Polygons can be formed indicating areas of homogeneous characteristics


Columns
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Rows
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Raster data
1
2
3
4
5
2
4
4
ID
Class
1
Sand
2
Grass
3
Water
4
House
5
Paving

Vector Format

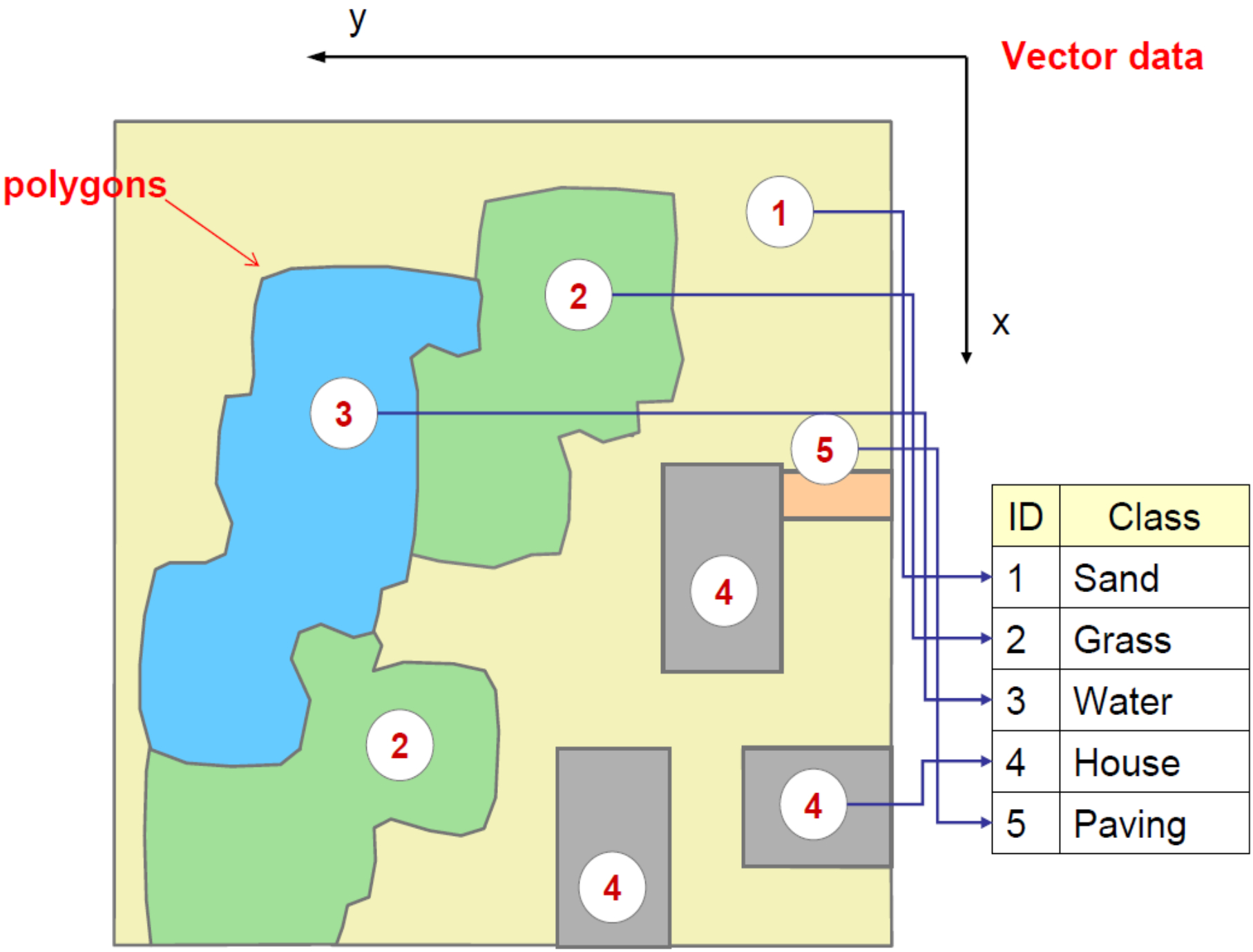
- Data are associated with points, lines, or boundaries enclosing areas
- Points are located by coordinates
- Lines are described by a series of connecting vectors (line segments described by the coordinates of the start of the vector, its direction, and magnitude or length).
- Areas or polygons are described by a series of vectors enclosing the area.

Vector Format

- Any number of factors or attributes can be associated with a point line or polygon.
- Data are stored in two files:
  - a file containing location information
  - a file containing information on the attributes
- A third file contains information needed to link positional data with their attributes.

Vector Data

- A vector system usually stores data as coordinates.
- For example Each uniform area is surrounded by a set of straight line segments called vectors.
- In a vector based system every point is recorded by a pair of x and Y coordinates.
- Straight line segments called vectors are displayed to indicate line based data (roads rivers wells)
- The x-y coordinates at the end of each vector can be digitized and stored.
- Most spatial features can be displayed as: - Points- Line- Polygons


y
x
Vector data
polygons
1
2
3
4
5
2
4
4
ID
Class
1
Sand
2
Grass
3
Water
4
House
5
Paving

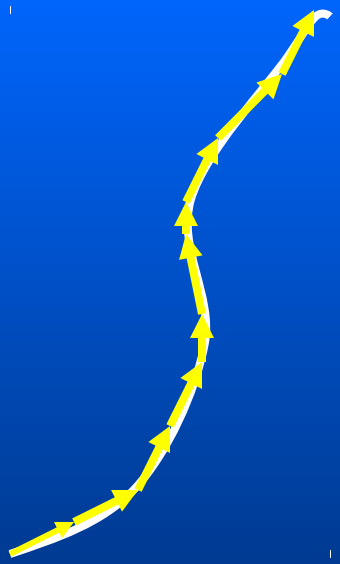
Vector and Raster Representation of *Point* Map Features

Map Feature	GIS Vector Format	GIS Raster Format
		
	(X,Y) Coordinate in space	Cell Located in an Array

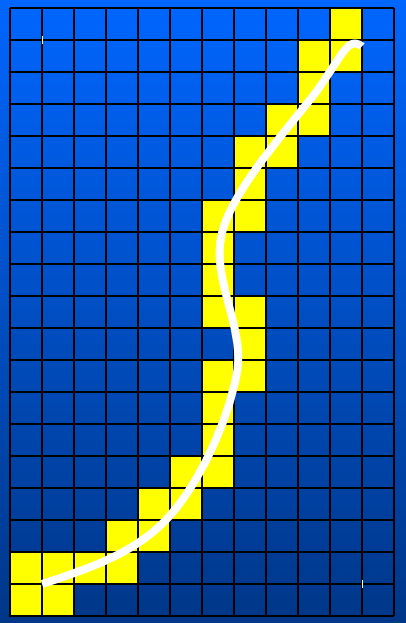
Vector and Raster Representation of *Line* Map Features

Map Feature

GIS Vector Format

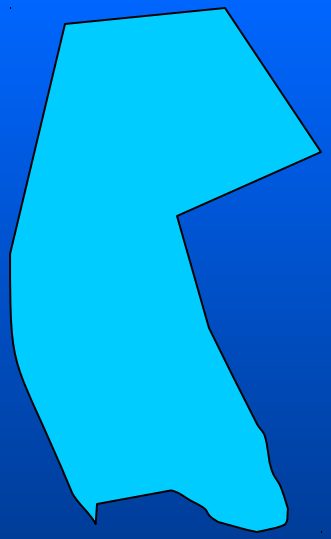


GIS Raster Format

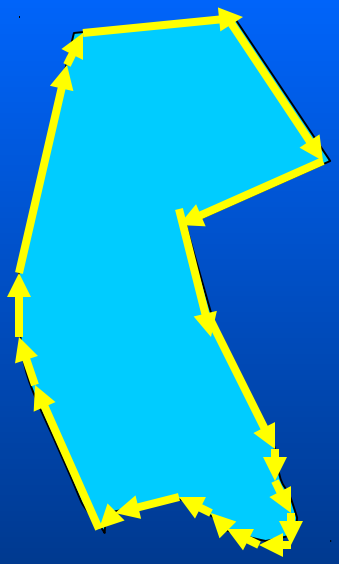


Vector and Raster Representation of *Area* Map Features

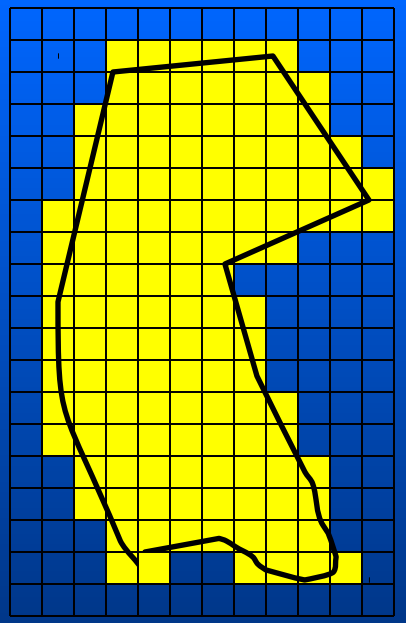
Map Feature



GIS Vector Format



GIS Raster Format



Comparison of Raster and Vector Formats

Raster

- Raster formats are efficient when comparing information among arrays with the same cell size.
- Raster files are generally very large because each cell occupies a separate line of data, only one attribute can be assigned to each cell, and cell sizes are relatively small.

Vector

- Vector formats are efficient when comparing information whose geographical shapes and sizes are different.
- Vector files are much smaller because a relatively small number of vectors can precisely describe large areas and a many attributes can be ascribed to these areas.

Comparison of Raster and Vector Formats

Raster

- Raster representations are relatively coarse and imprecise

Vector

- Vector representations of shapes can be very precise.

Most GIS software can display both raster and vector data. Only a limited number of programs can analyze both types of data or make raster type analyses in vector formats.

Attribute Data

- Attributes can be numeric or alfa-numeric data that is assigned to a point, line or area spatial features

- Example Attributes…

  Stand ID, Compartment No., Vegetation type, Name of the Forest Block, Types of Road, VSS code etc.,

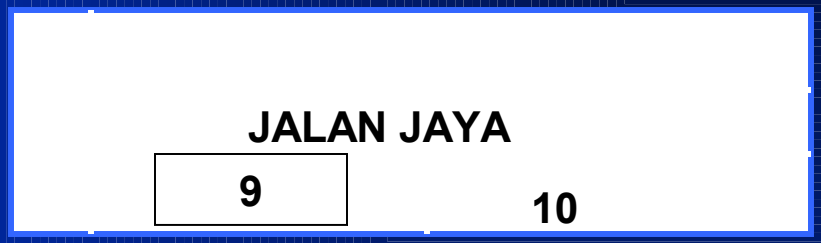
NATURE OF SPATIAL DATA (GEOGRAPHIC OBJECTS)

- spatial component
  - relative position between objects
  - coordinate system
- attribute component
  - explains spatial objects characteristics
- spatial relationship
  - relationship between objects
- time component
  - temporal element

SPATIAL DATA

SPATIAL

NON-SPATIAL



MAP

ADDRESS	NAME
9, JALAN JAYA	HAMID
10, JALAN JAYA	LUKE

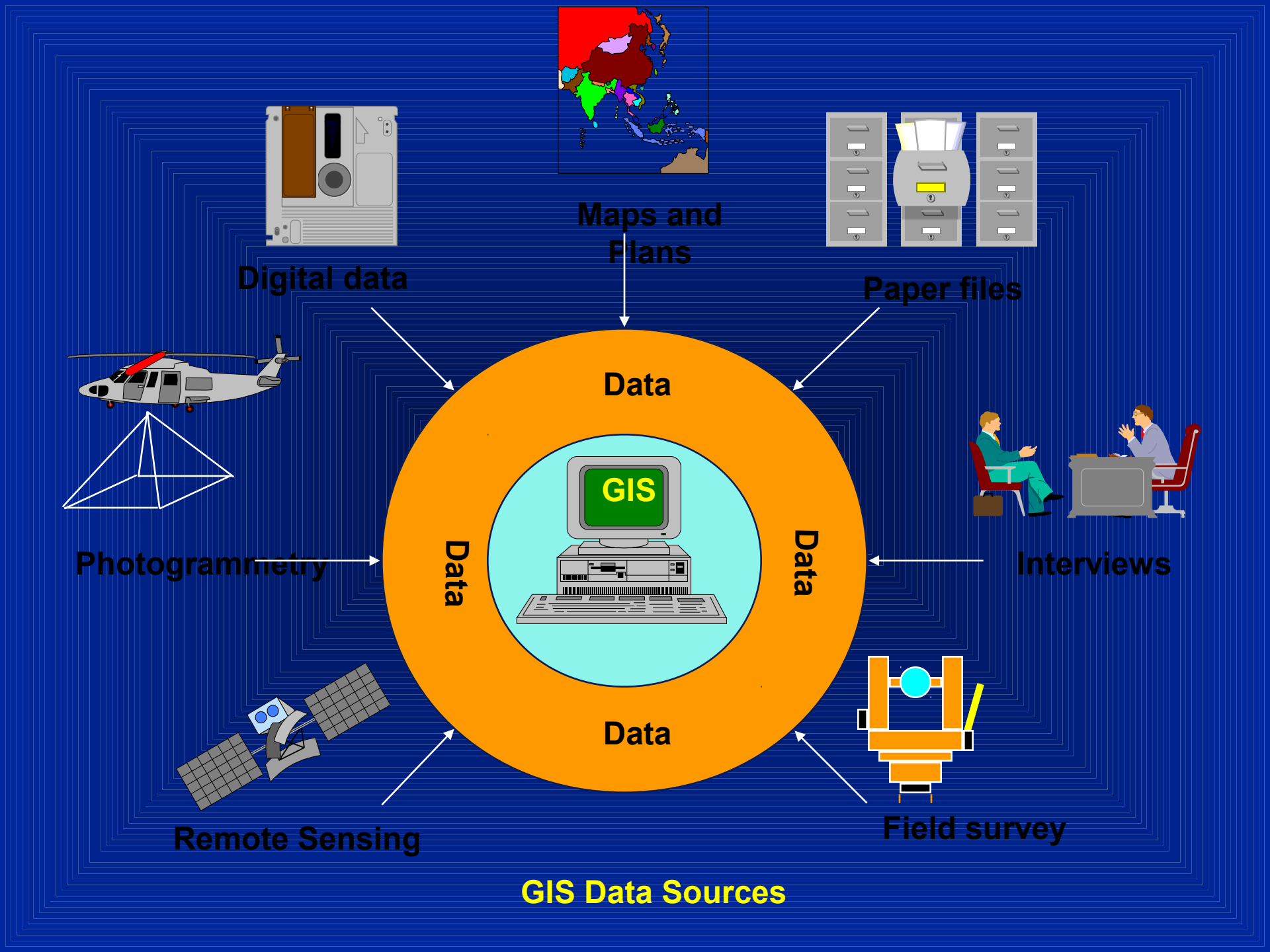
DATABASE

SPATIAL DATA CRITERIA:

- X-Y Coordinate System
- Shape
- Area/Size
- Perimeter
- Distance
- Neighborhood

ATTRIBUTES:

- Explains about spatial data
- Relevant non-spatial data
- Words or Numbers
- Qualitative methods
- Quantitative methods

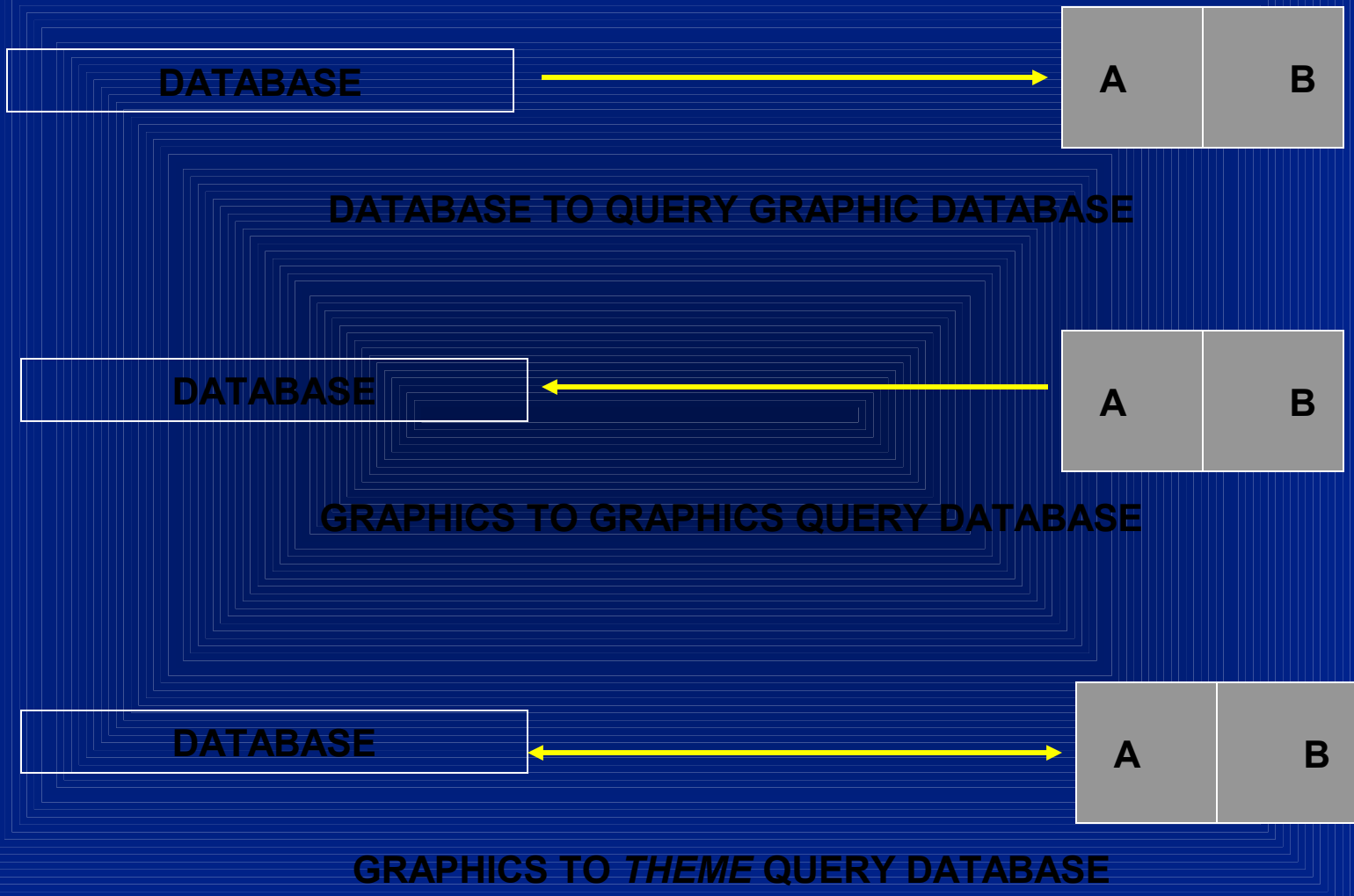


GIS Data Sources

DATA SOURCES

- Existing data
  - digital
  - map and plan
  - paper files
    - low cost
- acquisition
  - remote sensing
  - photogrammetry
  - field survey
    - high cost

QUERY ON DATABASE AND GRAPHICS



AVAILABLE DIGITAL DATA

- original format sometimes need to be changed into targeted format. (See example in hand-outs.)
- data maybe built for different purposes
  - quality of data not known

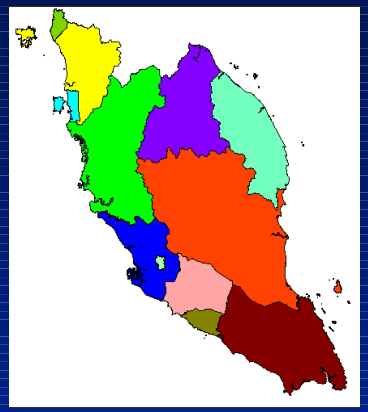
SPATIAL COMPONENT FROM MAPS AND PLANS

- need to be changed into digital format
  - scanning
  - digitizing
  - keyboard entry
    - coordinates
    - field survey data
- the quality of data is known and controlled

Scanning

Keyboard entry

Digitizing



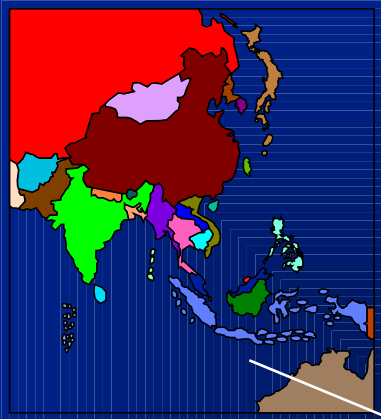
Producing Digital Data

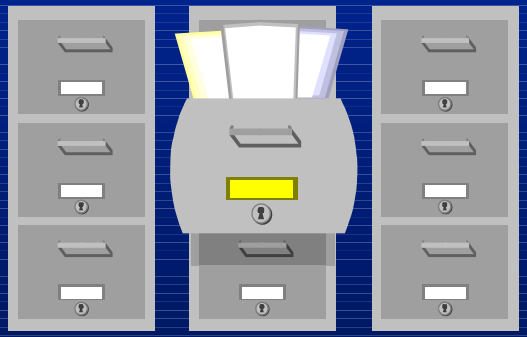
DATA ACQUISITION

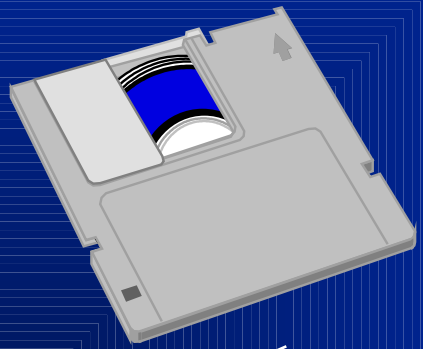
- spatial component can be obtained by
  - remote sensing
  - photogrammetry
  - survey
- attribute component can be obtained by
  - remote sensing/photogrametry
  - interviews
  - field visit

ATTRIBUTE COMPONENT

- retype from maps, plans or hardcopy files
- copied from existing digital data







Attribute #1

Attribute #2

Attribute #3

.

.

Attribute #n

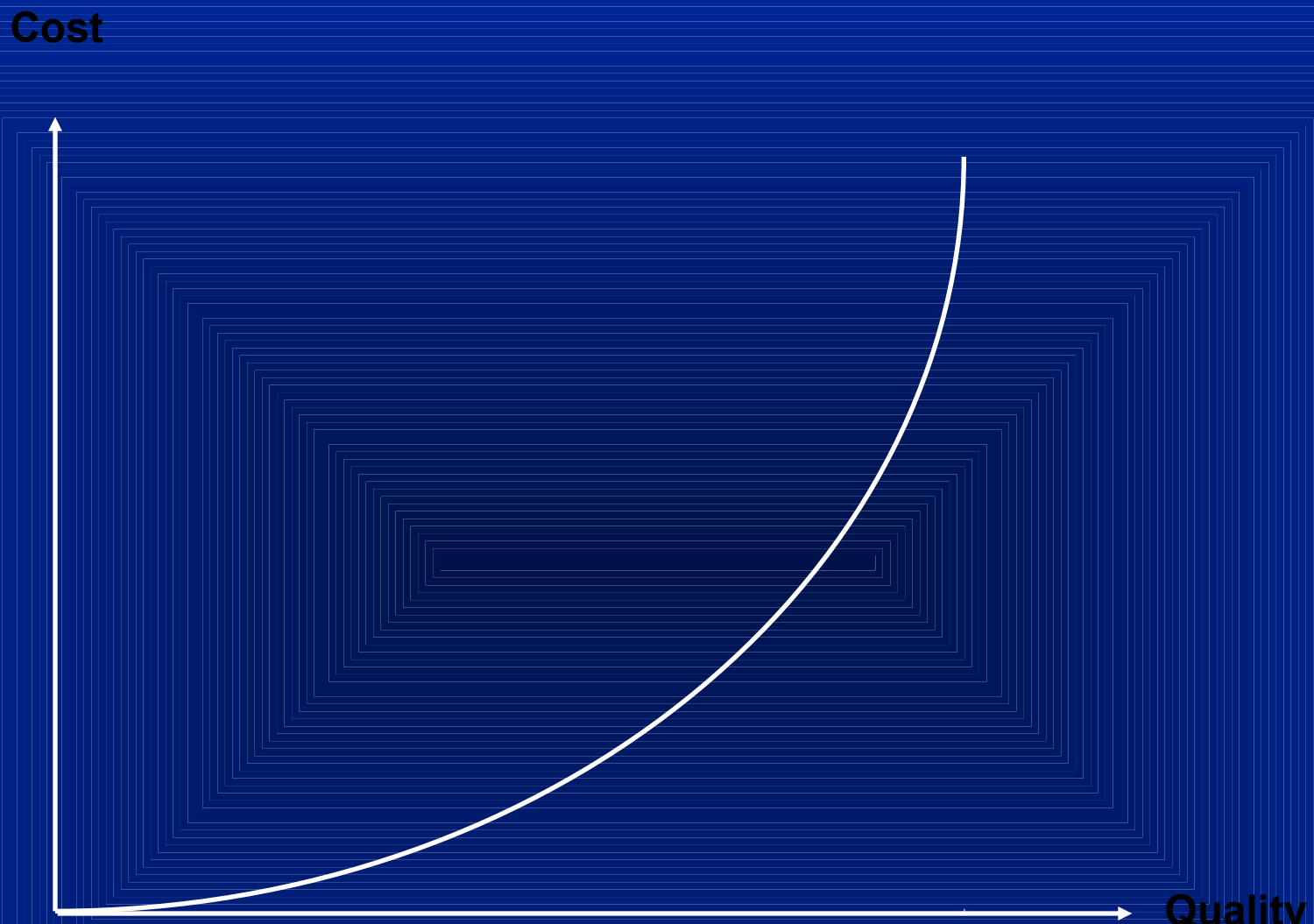
Attribute Component

DATA ENTRY

- involves 75% of total implementation cost
- majority of data entry methods require a lot of time
- data sharing enables lower data costs i.e. existing data

DATA QUALITY (I)

- misconception that data from GIS is of higher quality
  - GIS uses the latest technology
- quality of GIS information depends on quality of data
  - ‘garbage in garbage out’ (GIGO)
- conventional method, users decide for their own
  - GIS?



Data Quality

SPATIAL ACCURACY

- Precision - indicates how closely several positions fall in relation to each other

- Accuracy - is a measure of the closeness of one or more positions to a position that is known and defined in terms of an absolute reference system.

ERROR SOURCES (I)

- data acquisition
  - device/instrument errors
  - data entry errors
  - image interpretation error
- data conversion
  - instrument inaccuracies
  - device/instrument operator
  - manuscript used

ERROR SOURCES (II)

- data storage
  - digital representation limits
  - disk storage limits
    - used by huge raster formats
- data processing
  - rounding off error
    - digital representation
  - error propagation law
    - information derived by mathematical operations no more accurate than original information

GEO-SPATIAL ANALYSIS

INTRODUCTION

- **Geospatial analysis** is an approach to applying statistical methods and other informational techniques to data which has a geographical or geospatial aspect. Such analysis would typically employ software capable of geospatial representation and processing, and apply analytical methods to terrestrial or geographic datasets, including the use of GIS.

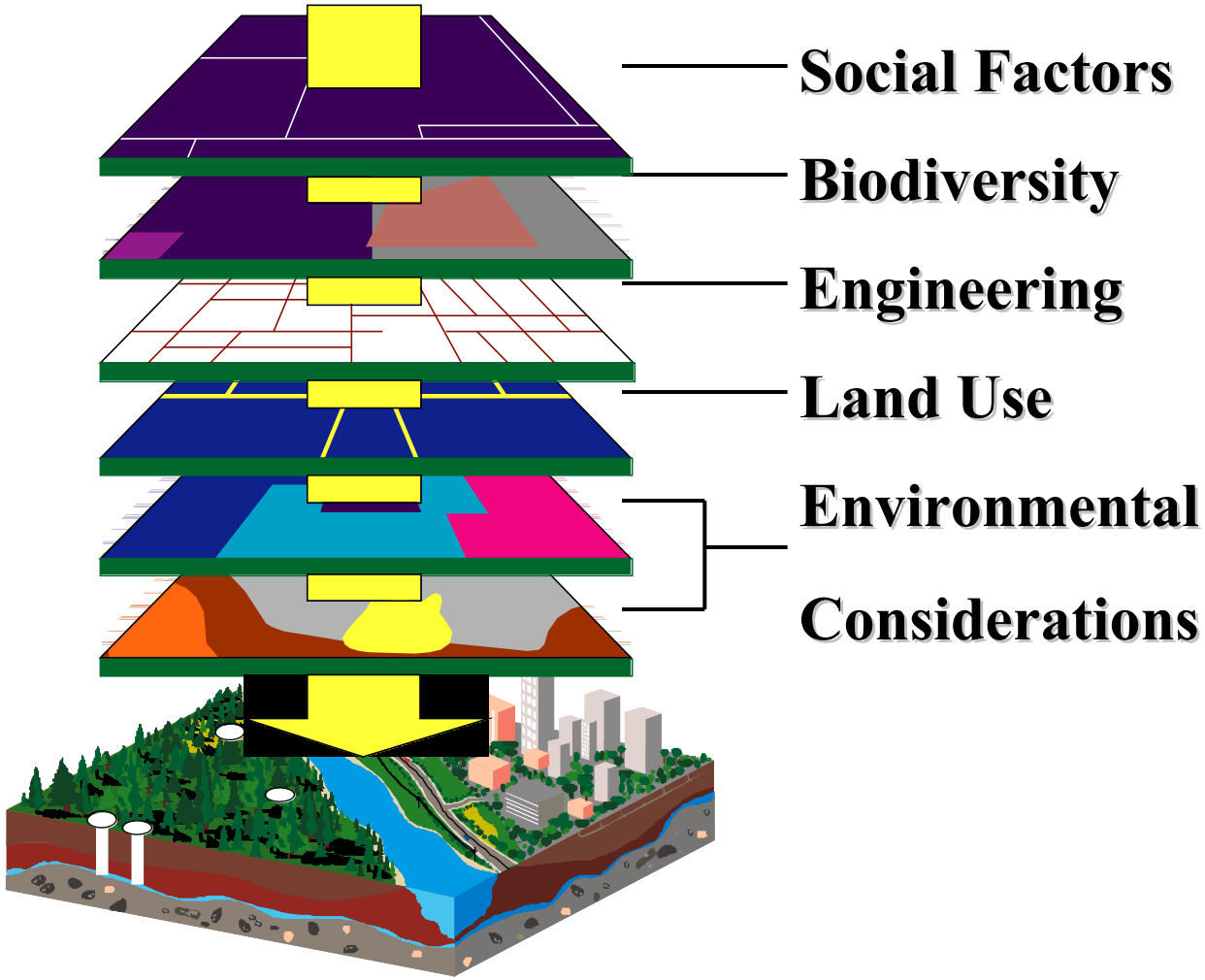
BASIC APPLICATIONS

- Geospatial analysis, using GIS, was developed for problems in the environmental and life sciences, in particular ecology and geology and It has extended to almost all industries including defence, intelligence, utilities, Natural Resources (i.e. Oil and Gas, Forestry etc.), social sciences, medicine and Public Safety (i.e. emergency management and criminology). Spatial statistics typically result primarily from observation rather than experimentation.

OPERATIONS:

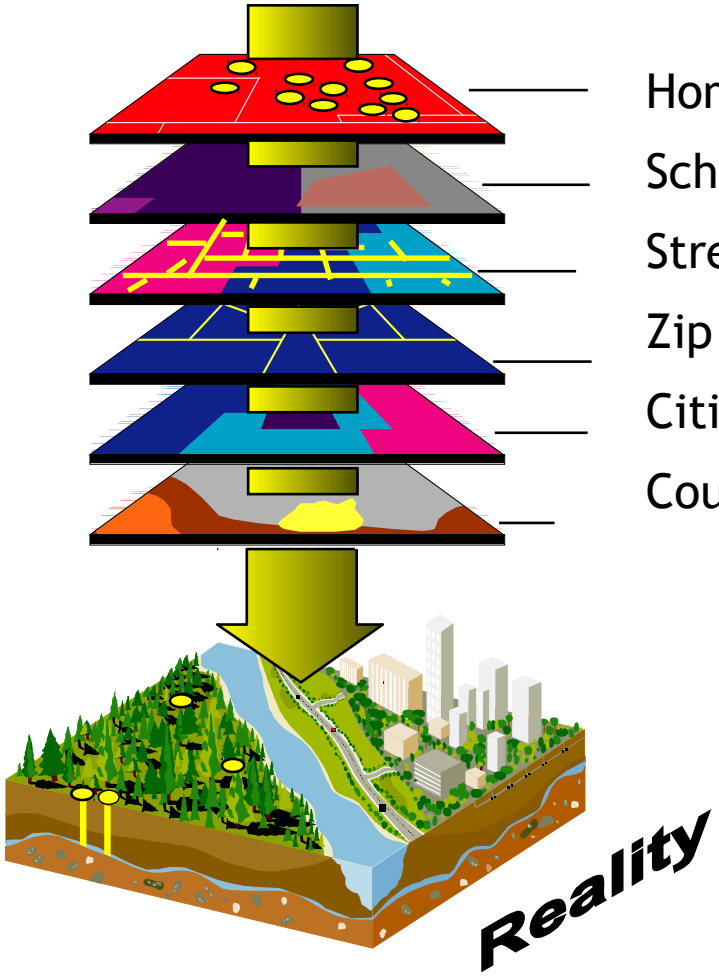
- **Surface analysis** —in particular analysing the properties of physical surfaces, such as gradient, aspect and visibility, and analysing surface-like data “fields”.
- **Network analysis** — examining the properties of natural and man-made networks in order to understand the behaviour of flows within and around such networks; and locational analysis.
- **Geovisualization** — the creation and manipulation of images, maps, diagrams, charts, 3D views and their associated tabular datasets.

MEASURING AND INTEGRATING THE PARTS

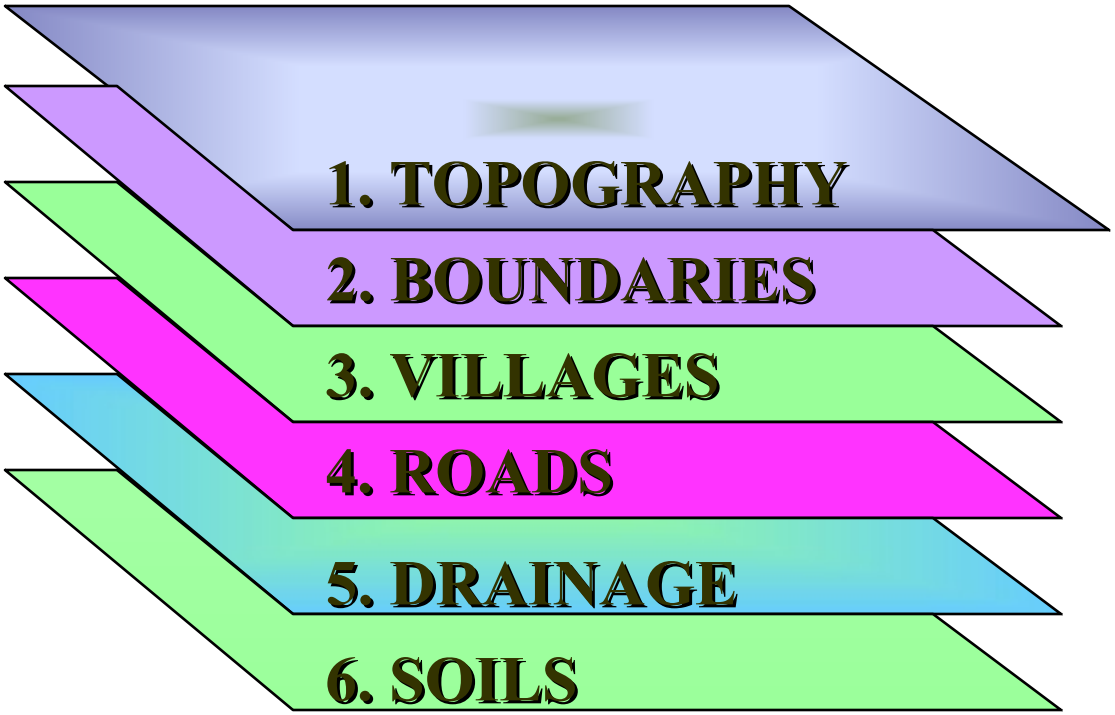


…Means Seeing the

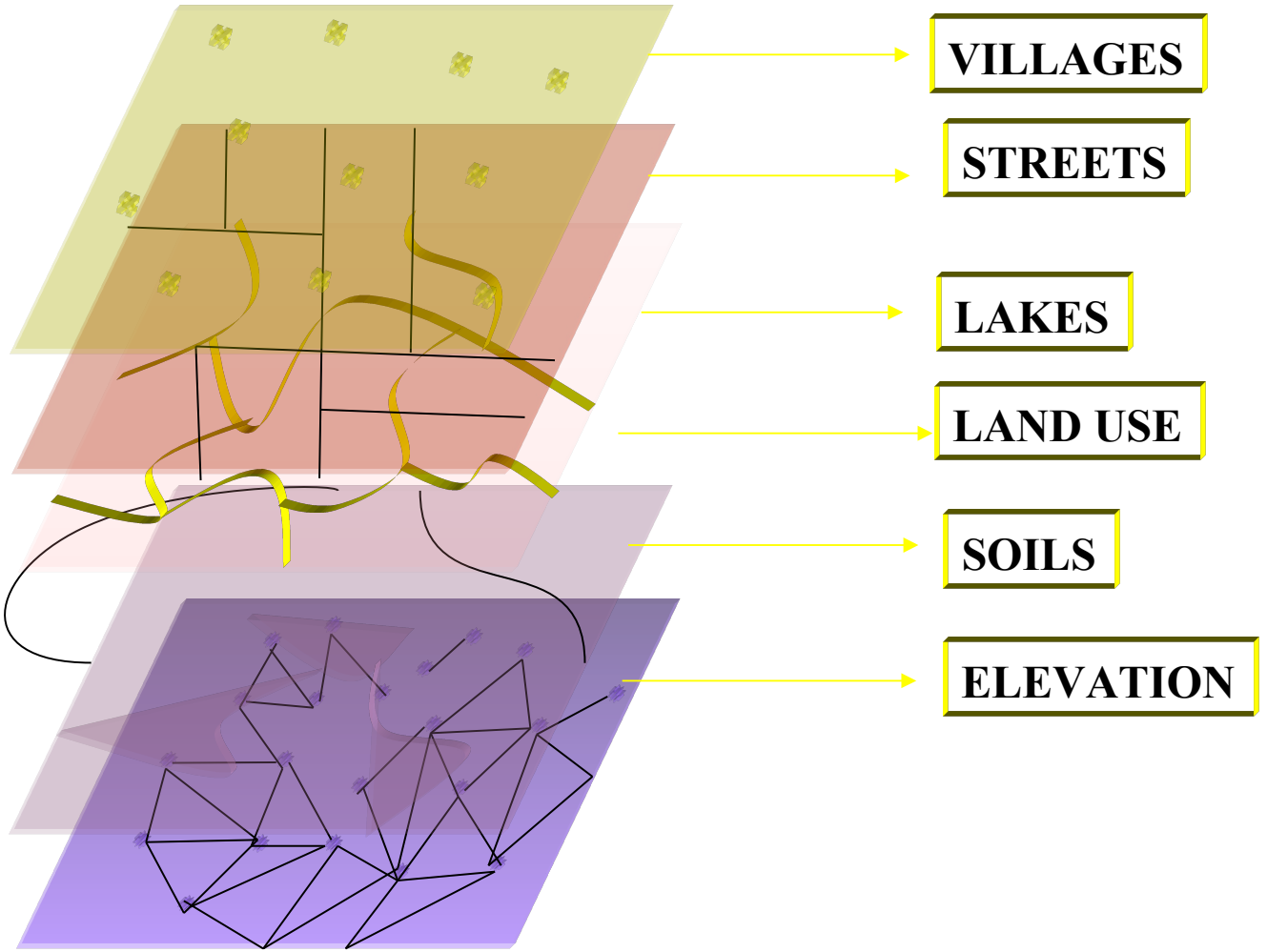
GIS INTEGRATES ALL THE PARTS. TO SEE THE WHOLE



Thematic Overlay

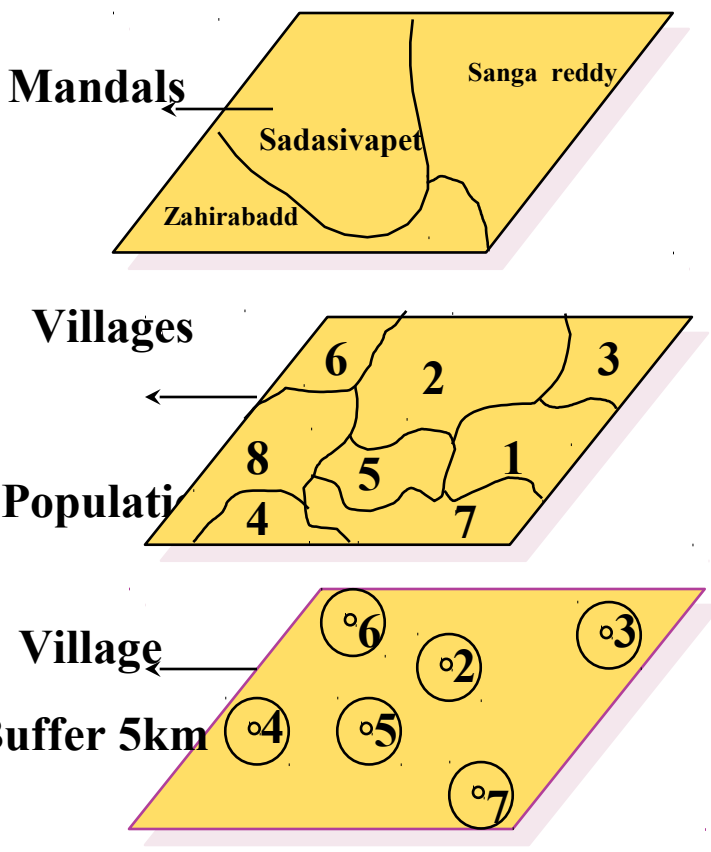


Thematic Overlay



Query and Analysis

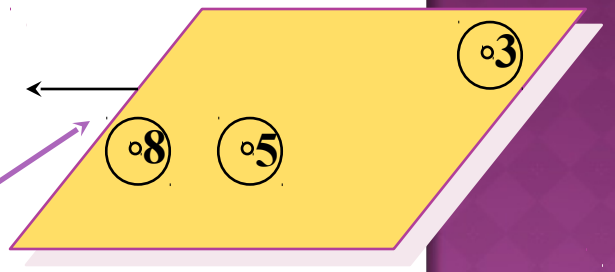
Data



Query

Identify villages where population is > 1000 but no school

Output



Report

3 villages of numbers 8,5and 3 are having population more than 1000 and with out a school.

Application of Geospatial analysis

Case study

Integrated GIS and Remote Sensing for Mapping Groundwater Potential Zones in NE Jordan

OBJECTIVES

1-To delineate the groundwater potential zones using relevant data (rainfall, topography, geology, soil, etc.)

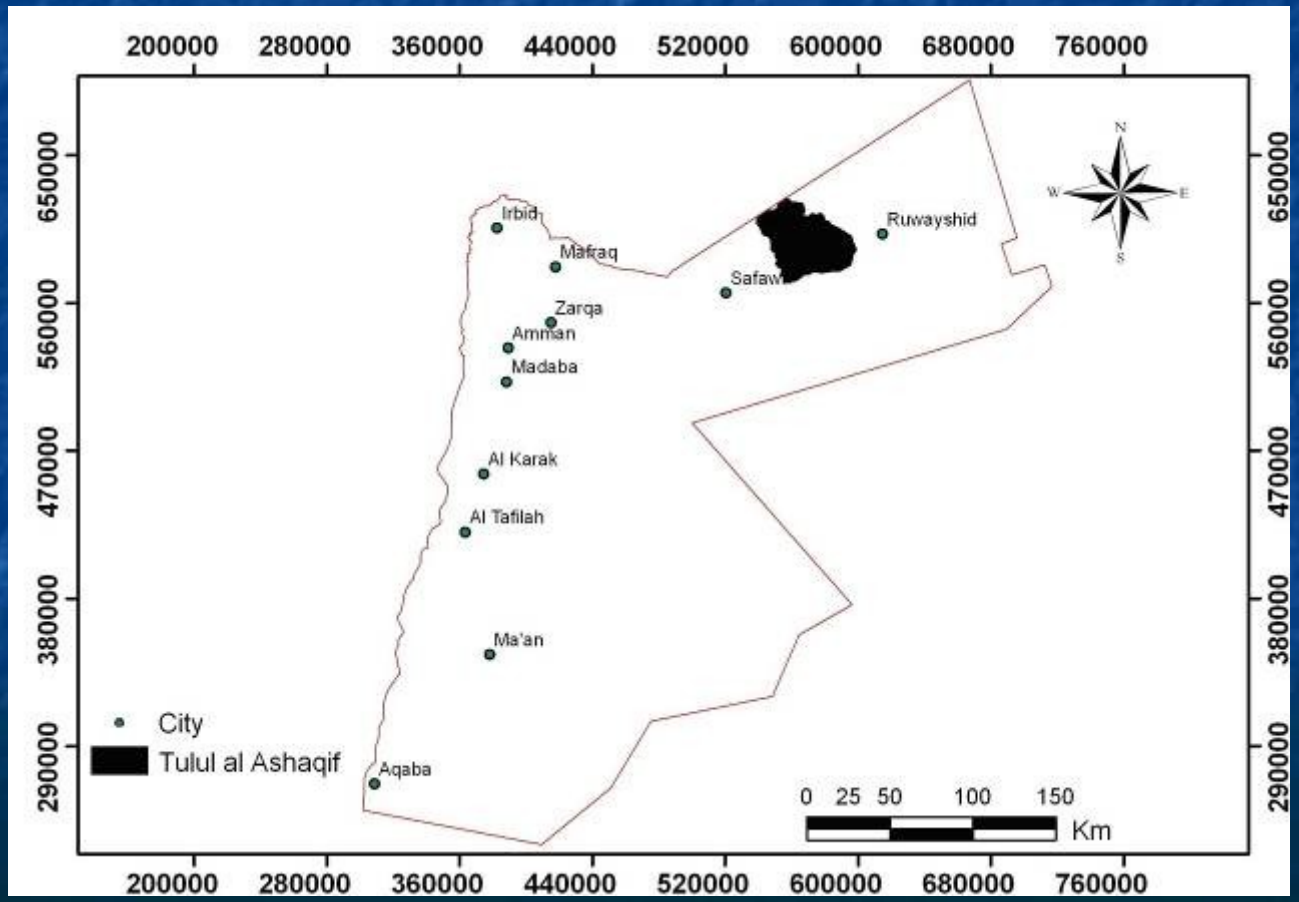
2-To develop a GIS model that can identify groundwater potential zones based on the thematic maps

3-To validate the results of this study with data from the field

Study Area: Tulul al Ashaqif highlands

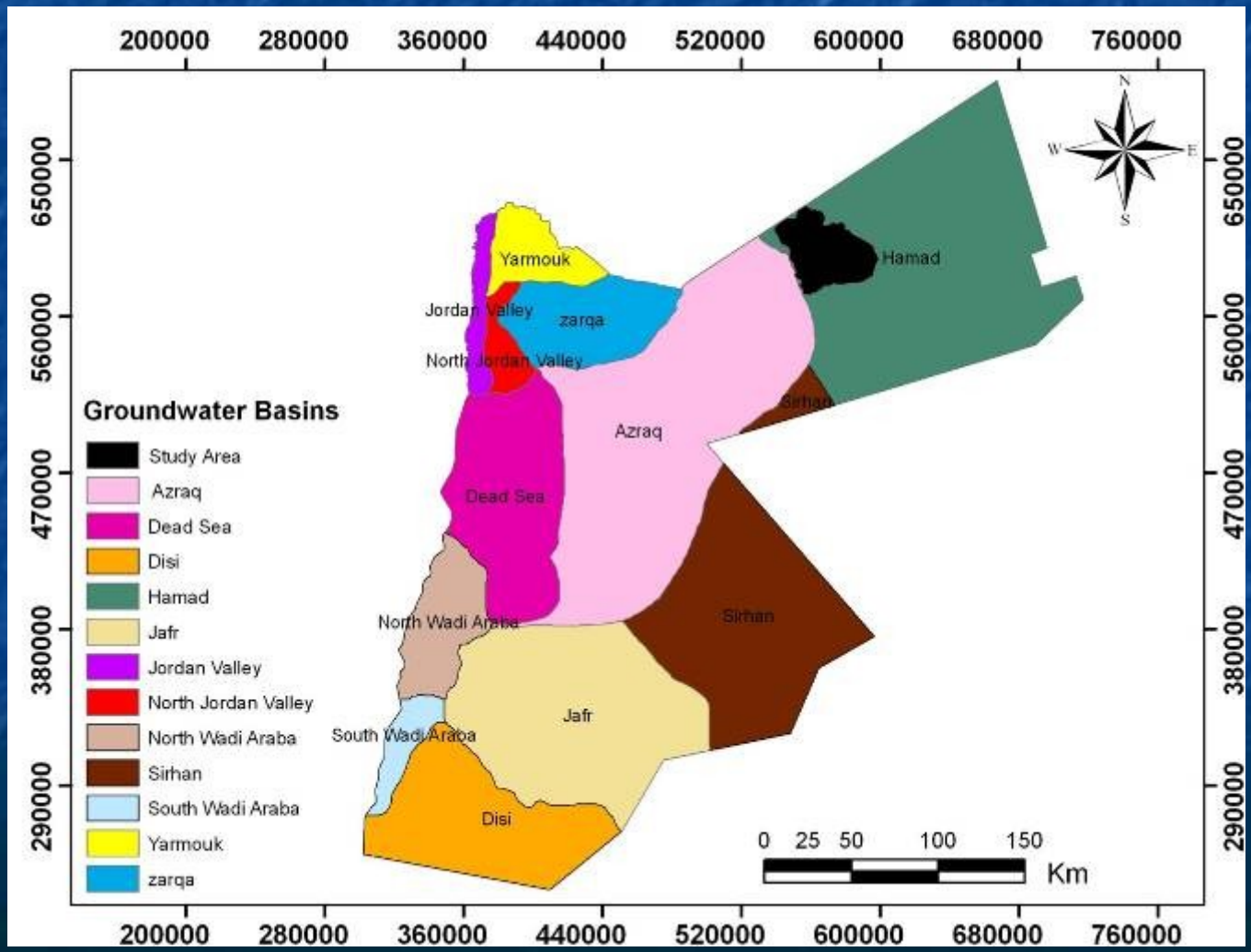
- a NW-SE ridge, part of the Badia region, NE Jordan
- 660 m -1050 m asl

- arid, and erratic rainfall spatially and Temporally with annual average 60-100 mm/yr



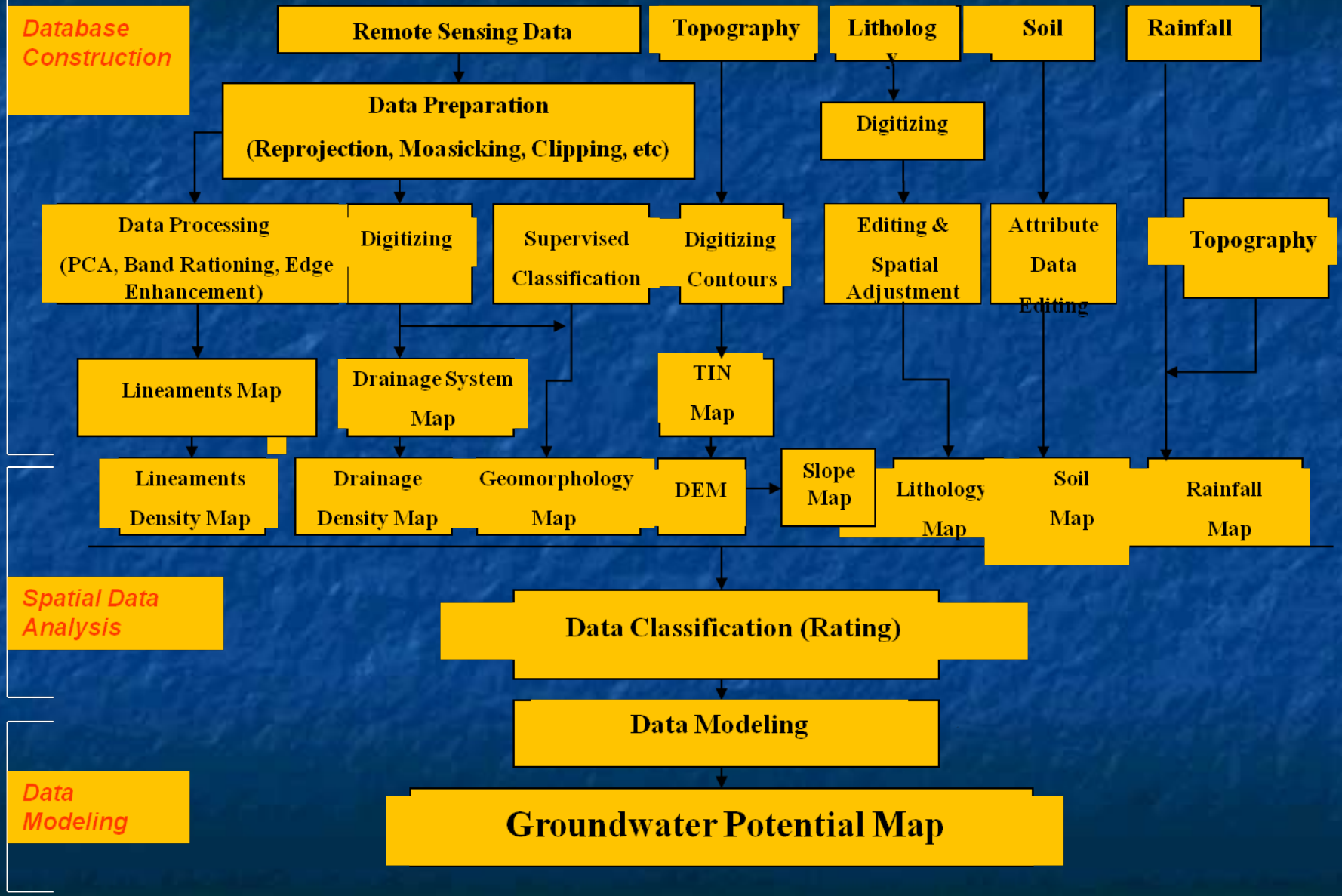
- the ridge defines the boundary between the Azraq and the Hamad hydrographic basins

- the ridge is of volcanic origin and Neogene in age



- largely covered by pavement overlying an eolian sedimentary mantl(

METHODOLOGY



- 8 thematic layers are selected:
  - geomorphology, soil texture, lithology, elevation, slope, annual rainfall, drainage density, and lineament density
- thematic layers were combined using weight index overlay method
- weights assigned to the data layers to reflect their relative importance
  - determined using analytical hierarchy principle (AHP)
- classes in each theme arranged in decreasing order of rating (0-100) based on previous work and experts

Weights and ratings

Parameter	Class	Rating	Weight
Elevation (m)	660-750	50	0.0156
	750-850	40	
	850-950	20	
	950-1050	10	
Soil	silty clay loam to clay	15	0.0455
	silty clay loam	20	
	very stony silty clay loam	30	
	often very gravelly, structured silty clay loam	30	
	stony and very stony silty clay loam to silty clay	30	
	silty clay loam and sandy clay	35	

Parameter	Class	Rating	Weight
	Mudflat	5	
	PV1	10	
	Ruggedland (Volcanic uplands)	20	
Geomorphology	PV2	20	0.1917
	PV3	30	
	Wadi	50	
	Marab	70	
	Alluvium mudflat	5	
	Pleistocene sediments	25	
Geology (Lithology)	Basaltic dyke	40	0.3487
	Volcanic	40	
	Alluvium and Wadi sediments	70	

Parameter	Class	Rating	Weight
Drainage density (Km/Km^2)	0-0.5	5	0.1917
	0.5-1	10	
	1-1.5	20	
	1.5-2	30	
	2-2.5	40	
	2.5-3	50	
	3-3.5	60	
	3.5-3.8	70	
Slope (degrees)	>10	10	0.0905
	5-10	25	
	2-5	30	
	0.5-2	35	
	0-0.5	40	

Parameter	Class	Rating	Weight
	90	70	
Rainfall (mm)	81	60	0.0905
	75	50	
	<1	20	
Lineament density (Km/Km2)	1-2	45	0.0258
	2-3	50	
	3-4.5	60	

Modelling

- The groundwater potential index value:

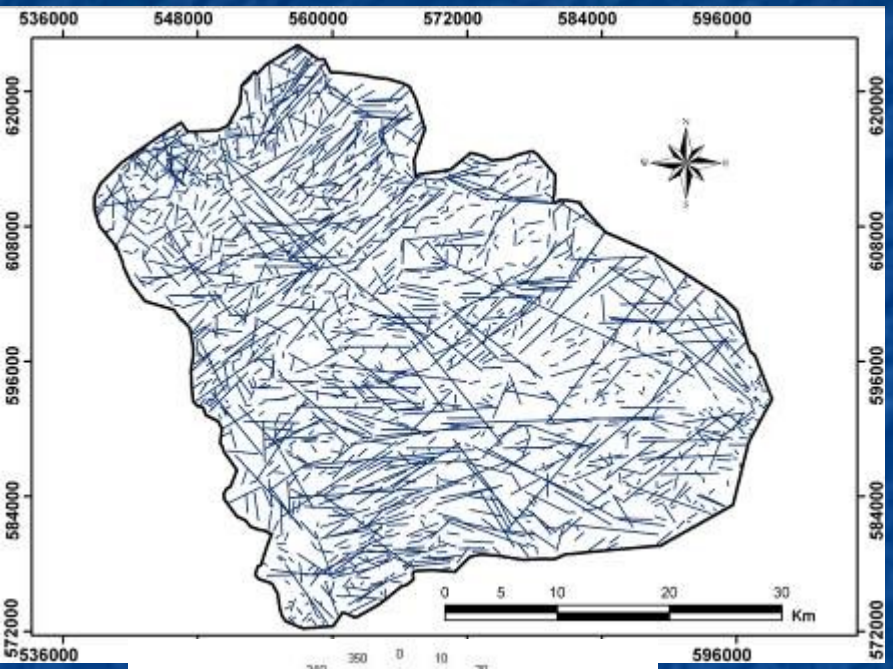
$$GPM = (Lw*Lr)+(Gw*Gr)+(Sw*Sr)+(LDw*LDr)+(Dw*Dr)+(Ew*Er)+(SLw*SLr)+(Rw*Rr)$$

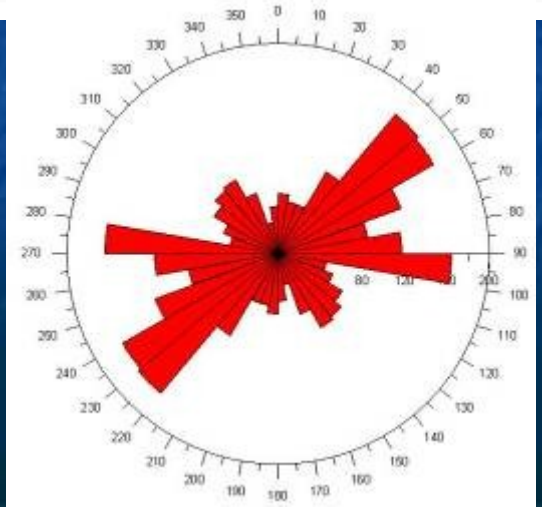
Where,

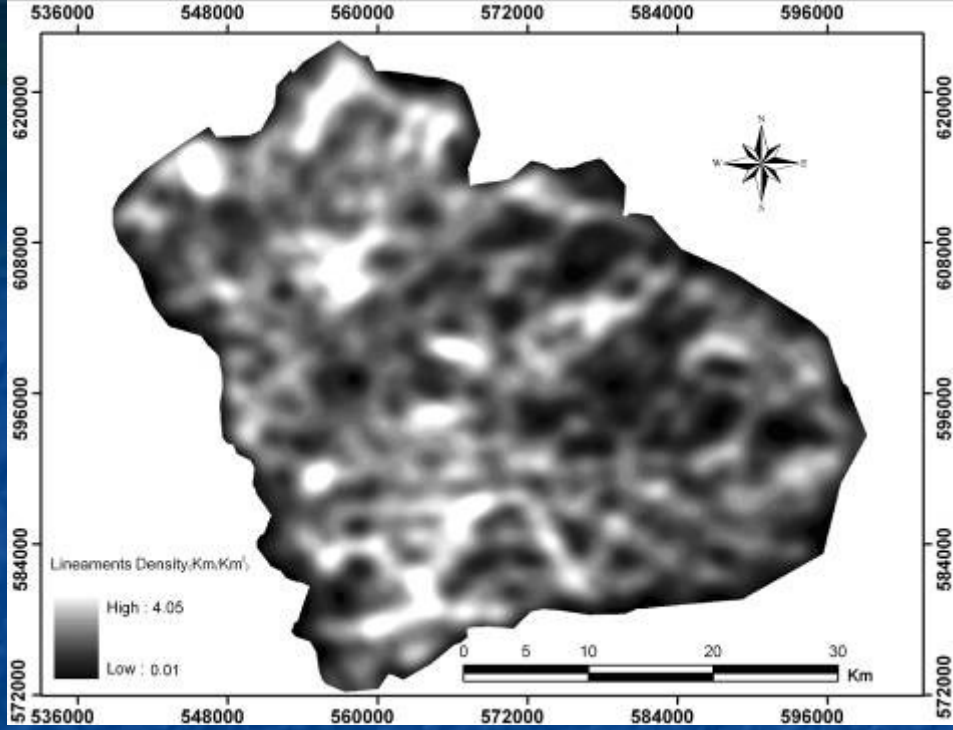
L = Lithology , G=Geomorpholgy, S= Soil, LD=Lineament Density, D=Drainage Density, E= Elevation, SL=Slope, R= Annual Rainfall, W= parameter weight, r= rating.

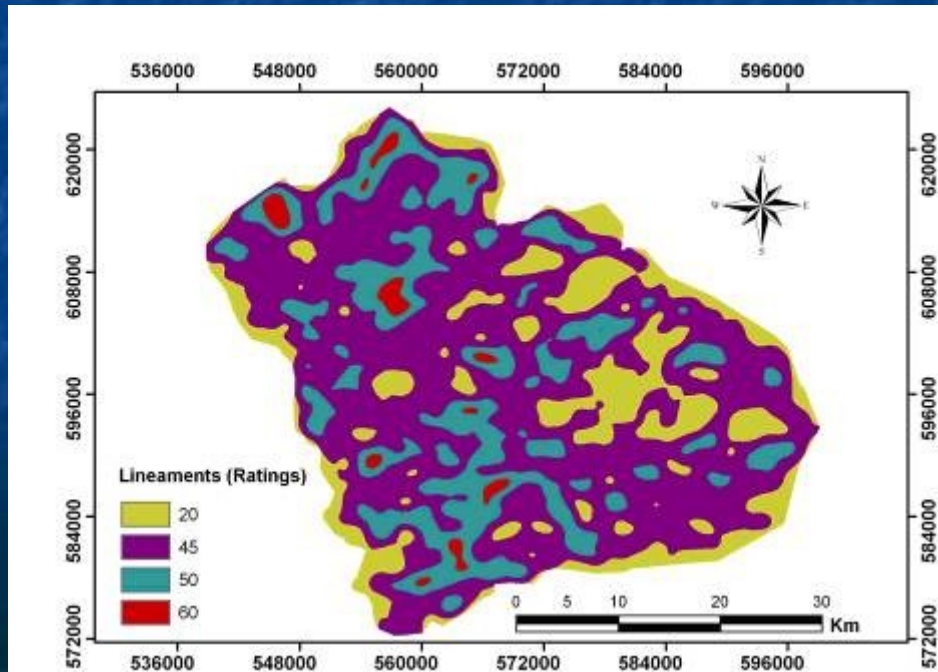
Results and Discussion

1. Lineaments Density

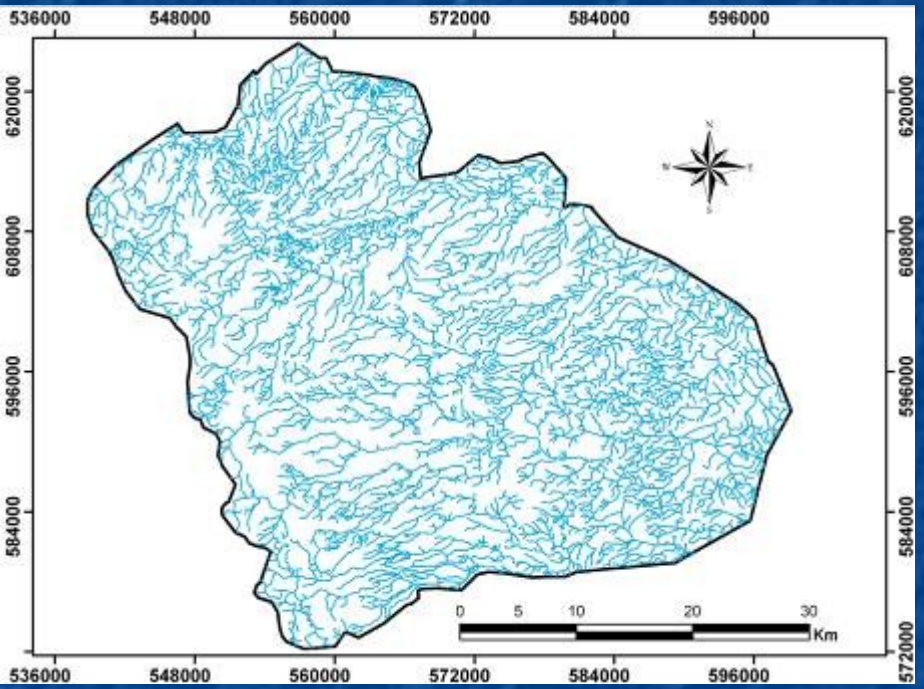


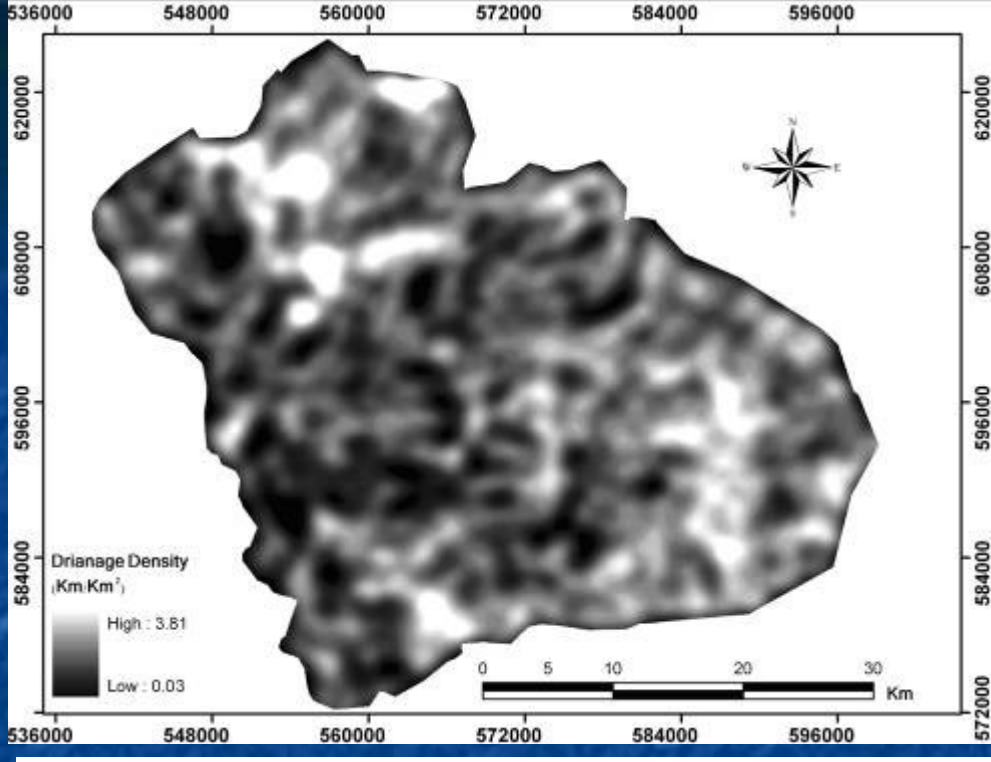


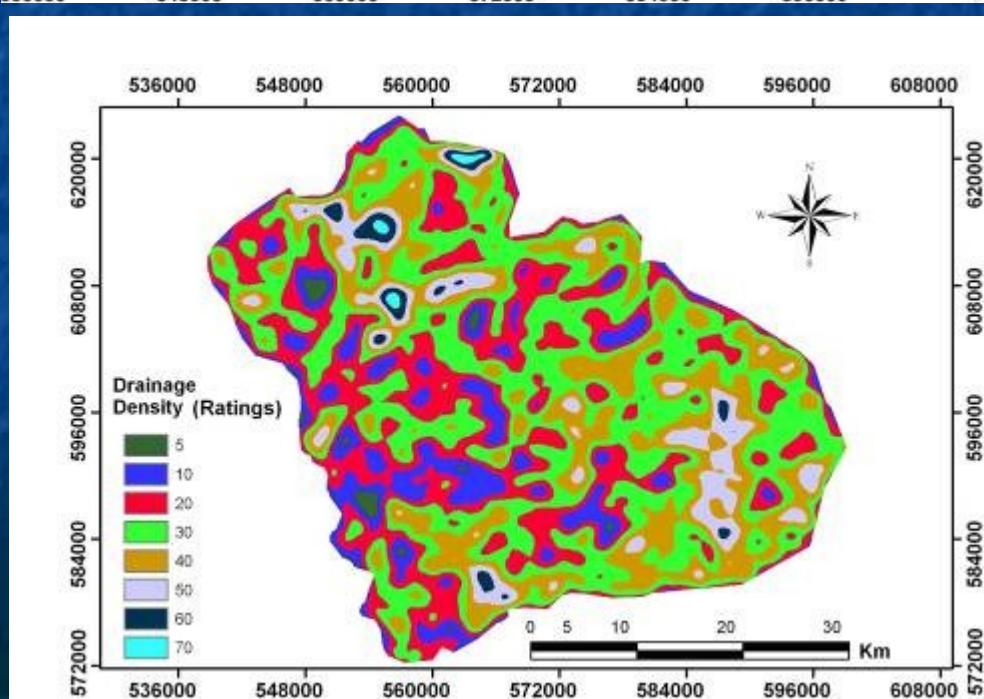




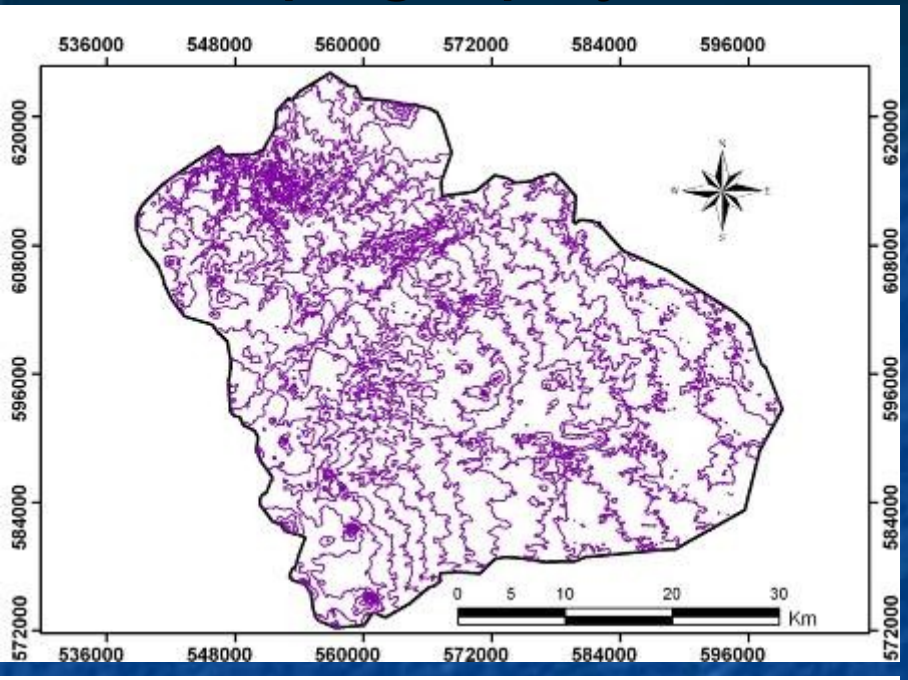
2- Drainage

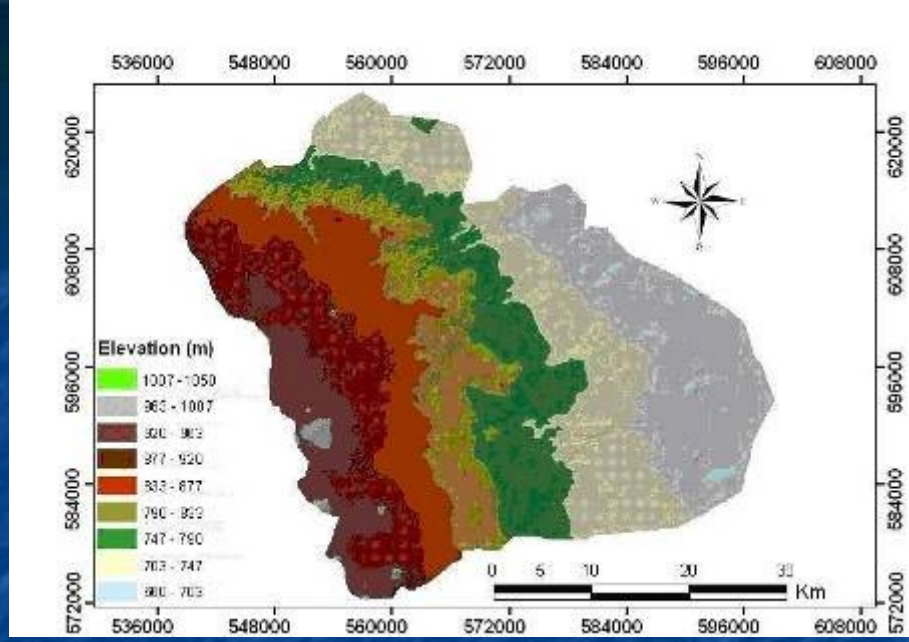

536000
548000
560000
572000
584000
596000
620000
608000
596000
584000
572000
0 5 10 20 30
Km

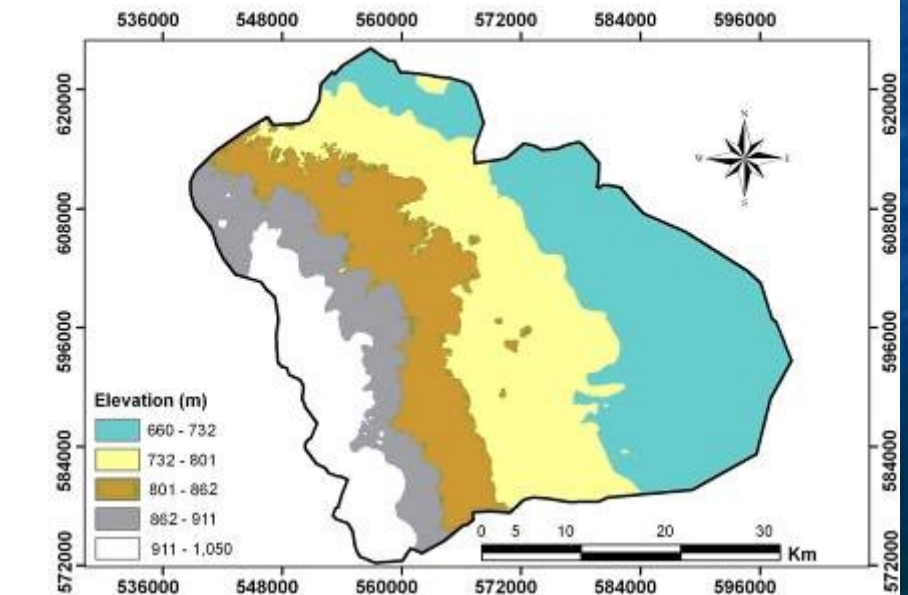

536000
548000
560000
572000
584000
596000
620000
608000
596000
584000
572000
Drianage Density
(Km/Km²)
High : 3.81
Low : 0.03
0 5 10 20 30
Km

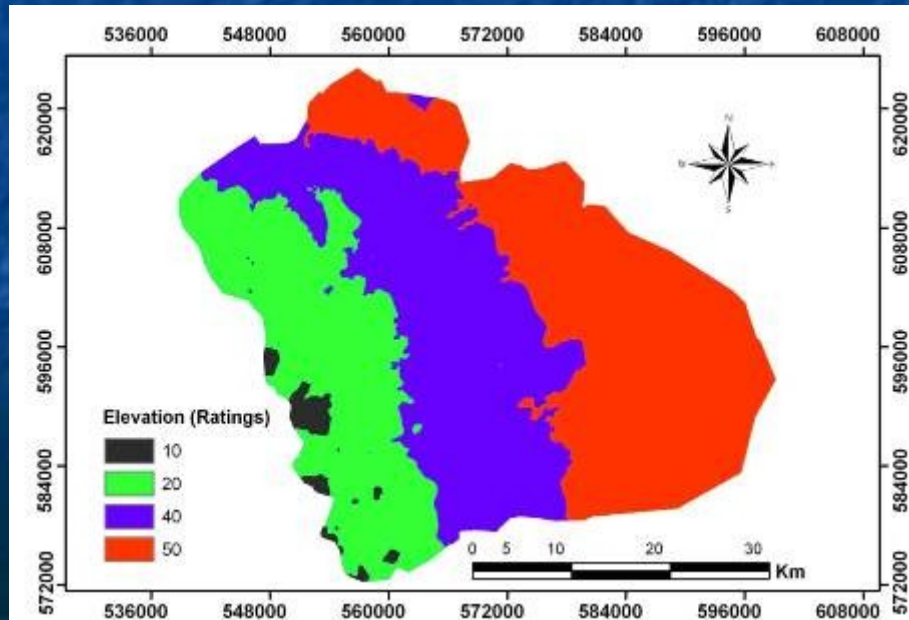

536000
548000
560000
572000
584000
596000
608000
620000
608000
596000
584000
572000
Drainage
Density (Ratings)
5
10
20
30
40
50
60
70
0 5 10 20 30
Km

3. Topography

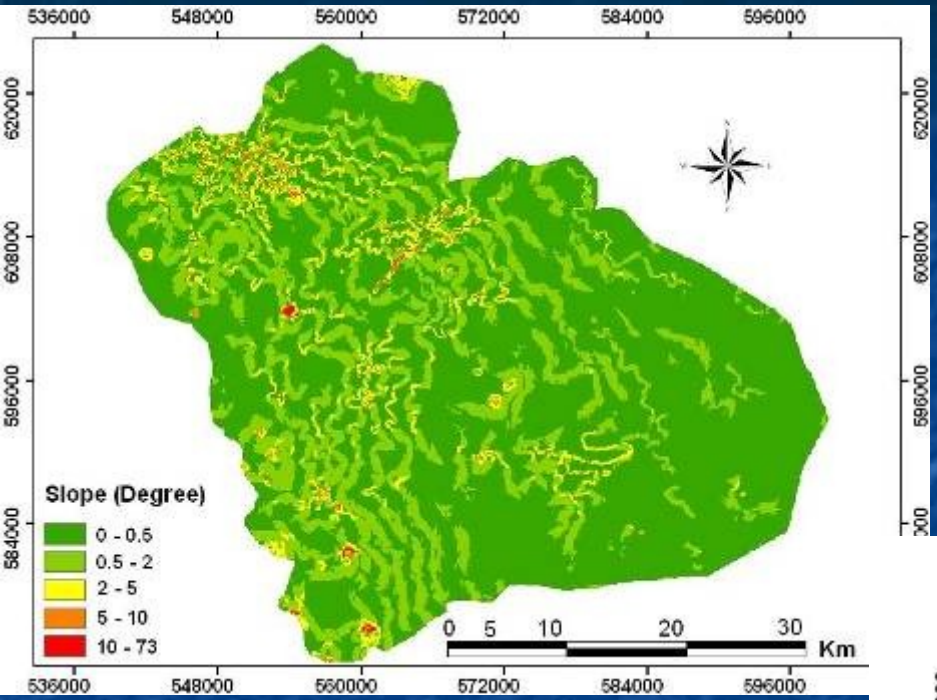


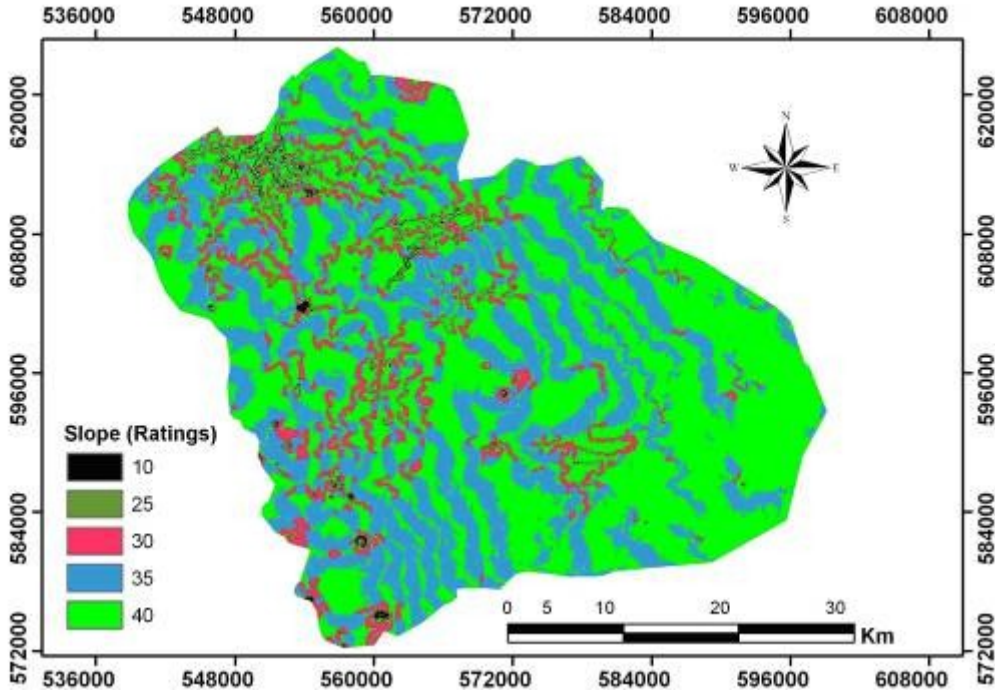






4. Slope


536000
548000
560000
572000
584000
596000
620000
608000
596000
584000
Slope (Degree)
0 - 0.5
0.5 - 2
2 - 5
5 - 10
10 - 73
0 5 10 20 30
Km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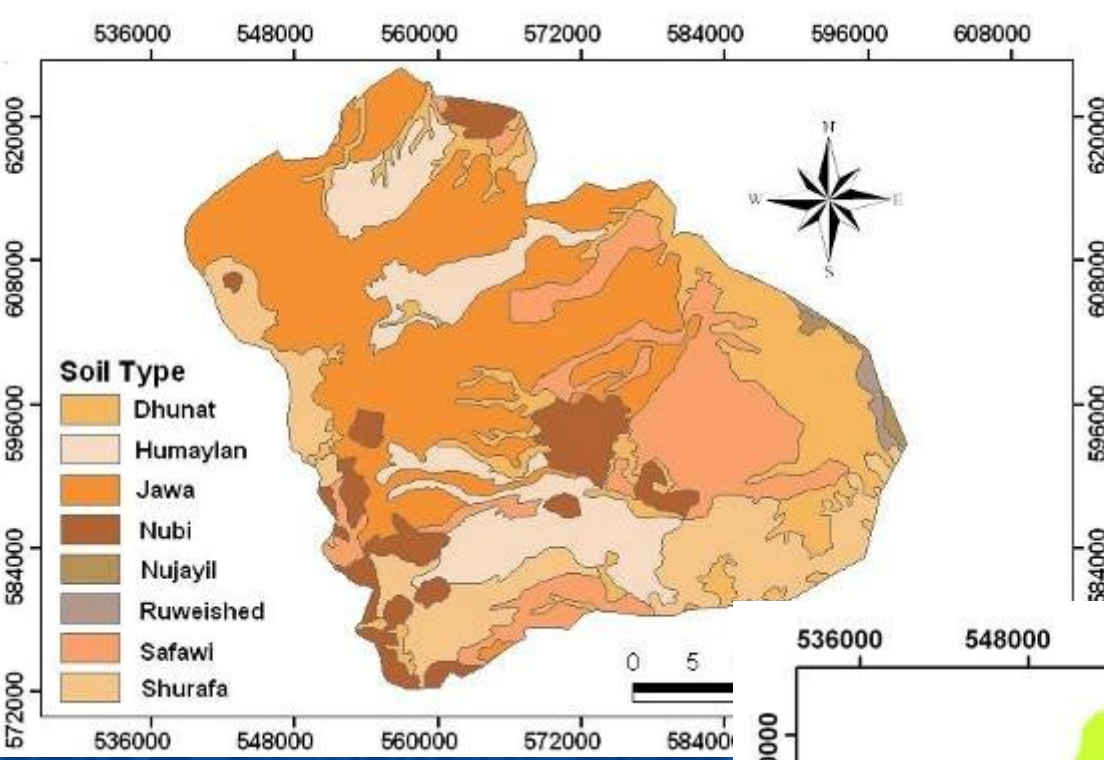
572000
Slope (Ratings)
10
25
30
35
40
0 5 10 20 30
Km

5. Soil

Unit Name	Symbol	Area (Km^2)	Texture
Nujayil	NUJ/17	7.8	Silty clay loam to clay
Ruweished	RUW/17	10.41	Silty clay loam to clay and sandy clay
Nubi	UBI/16	139.62	Stony and very stony silty clay loam to silty clay
Shurafa	SHA/16	246.89	Often very gravelly, structured silty clay loam
Humaylan	LAN/16	249.25	Very stony silty clay loam
Safawi	AWI/16	276.39	Silty clay loam
Dhunat	NAT/16	279.1	Silty clay loam
Jawa	JAW/16	631.19	Silty clay loam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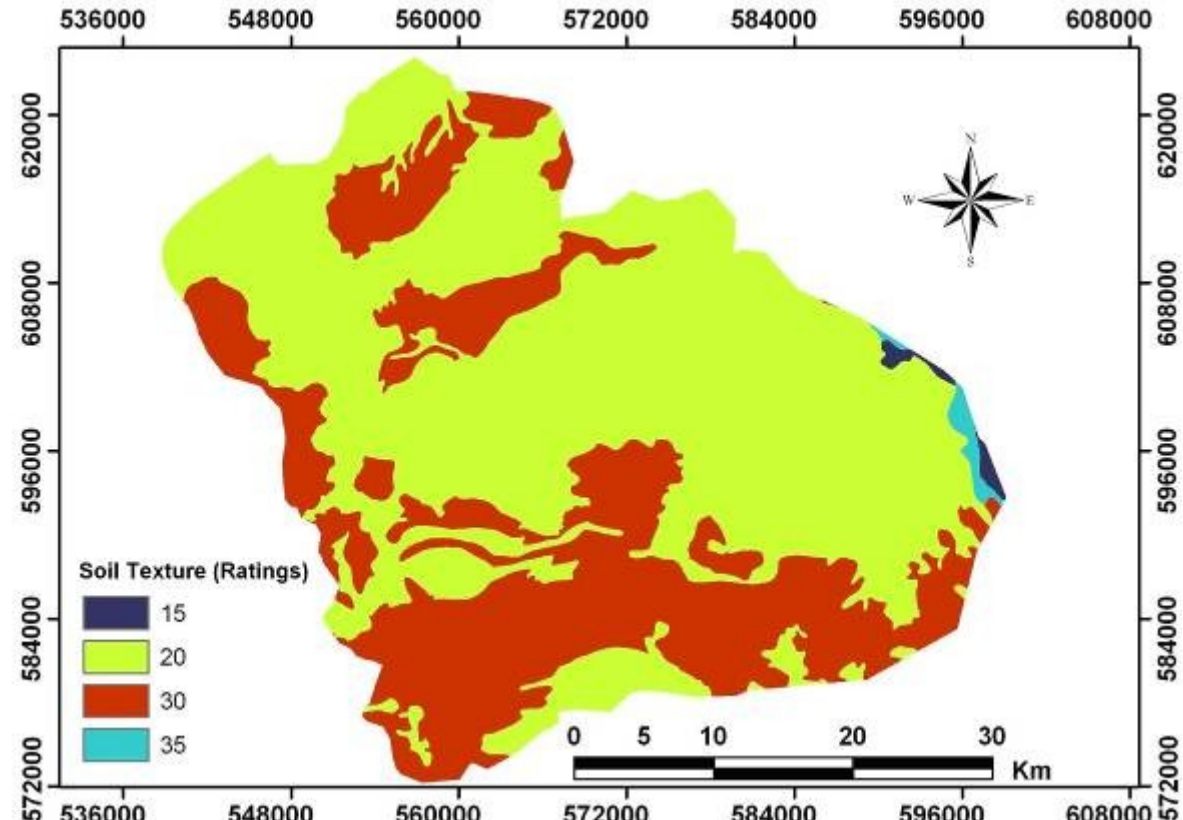
N
W
E
S
Soil Type
Dhunat
Humaylan
Jawa
Nubi
Nujayil
Ruweished
Safawi
Shurafa
0 5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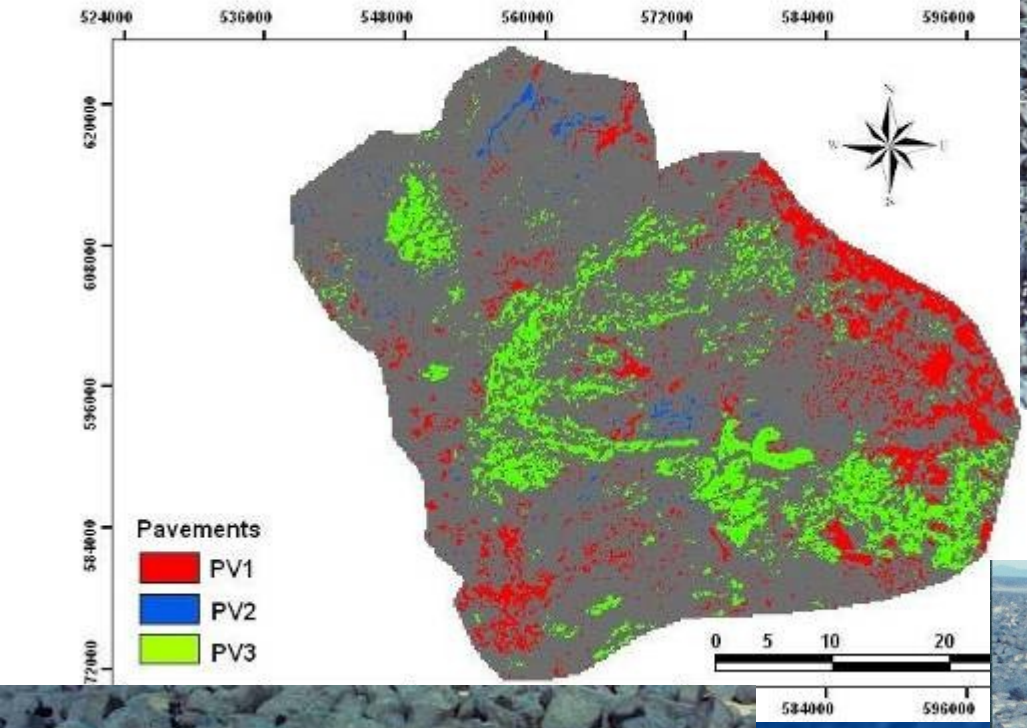
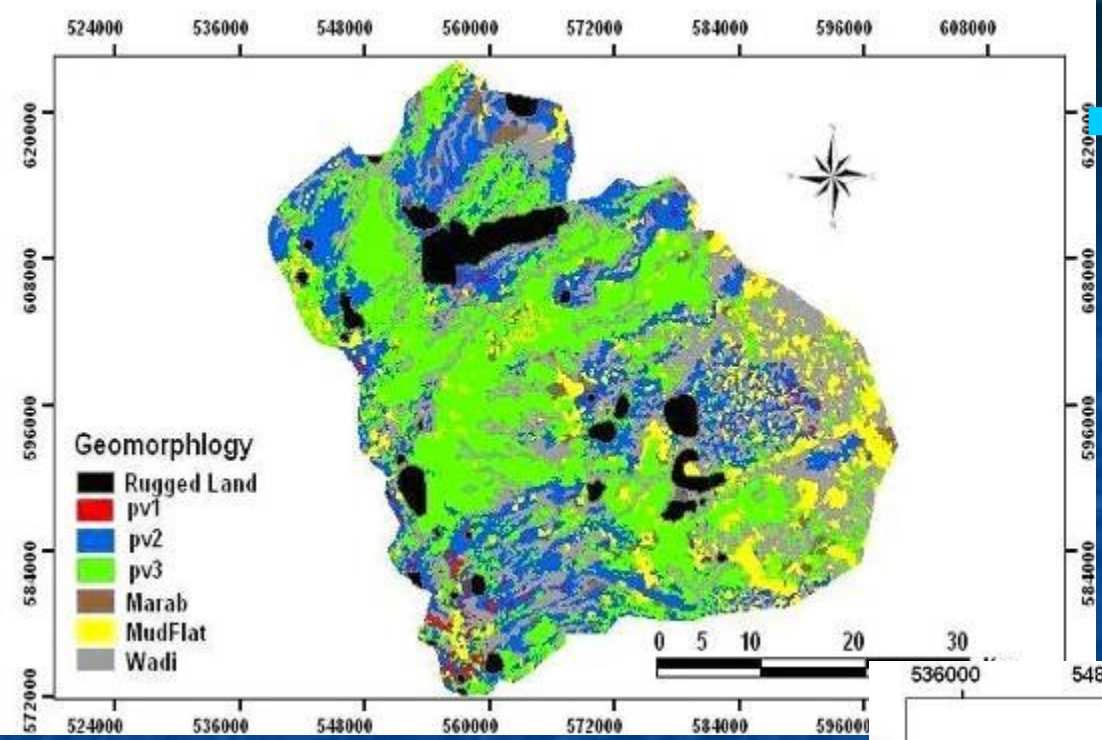
N
W
E
S
Soil Texture (Ratings)
15
20
30
35
0 5 10 20 30
Km

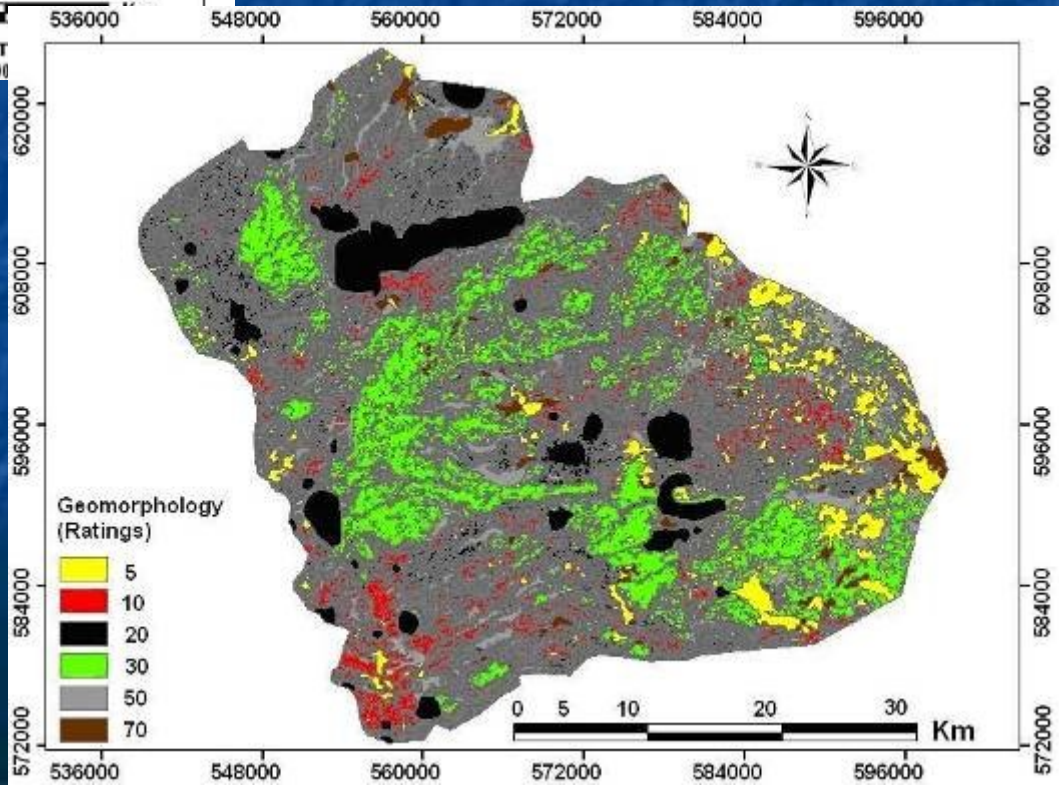
6. Geomorphology





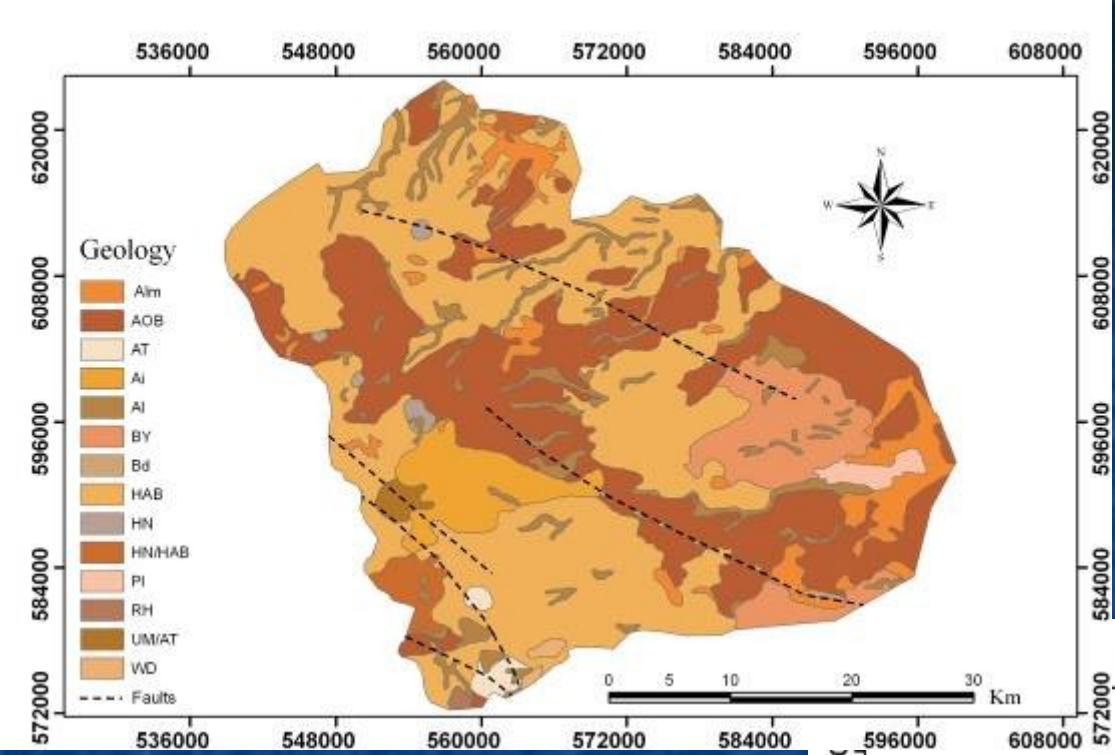
- **Marabs** are broad reaches filled with coarse sand and gravel typically have a relatively rich vegetative cover

- **Muflats** are fine-grained playa deposits that are almost totally devoid of vegetative cover



7. Lithology

Group	Symbol	Formation Name
Safawi Group	AOB	Abed Olivine Phyric Basalt Formation.
	AI	The Ali Doleritic Trachytic Basalt.
	RH	Rimah Group.
Rimah Group	AT	Aritayan Volcaniclastic Formation.
	HN	Hassan Scoriaceous Formation.
Rimah Group/ Asfar Group	HN/HAB	Hassan Scoriaceous Formation/Hashimyya Aphanitic Basalt.
Asfar Group/Rimah Group	UM/AT	Ufayhim Xenolithic Basalt Formation/Aritayan Volcaniclastic Formation.
Wisad Group	WD	Wisad Group.
Bishrihha Group	BY	Bishrihha Group.
Asfar Group	HAB	Hashimyya Aphanitic Basalt.
	Al	Alluvium.
	Pl	Pleistocene Sediments.
	Bd	Basalt Dyke.
	Alm	Alluvium Mudflat.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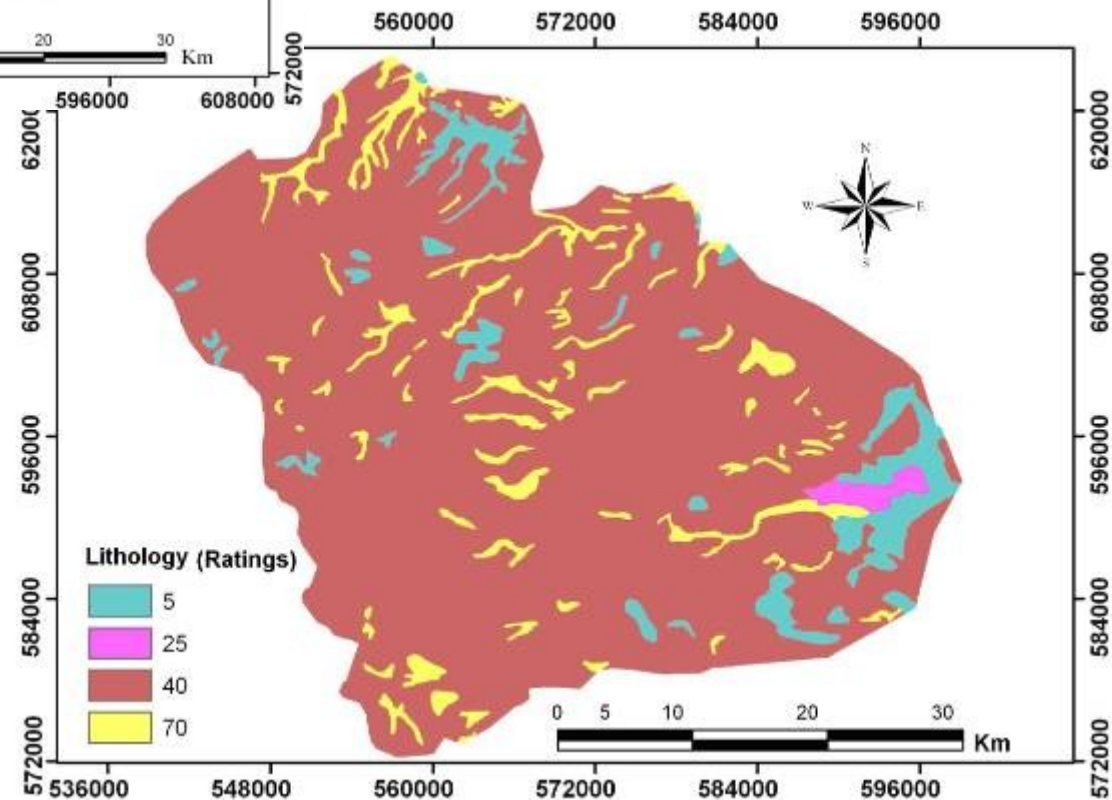
572000
Geology
Alm
AOB
AT
Ai
Al
BY
Bd
HAB
HN
HN/HAB
PI
RH
UM/AT
WD
Faults
N
W
E
S
0 5 10 20 30
Km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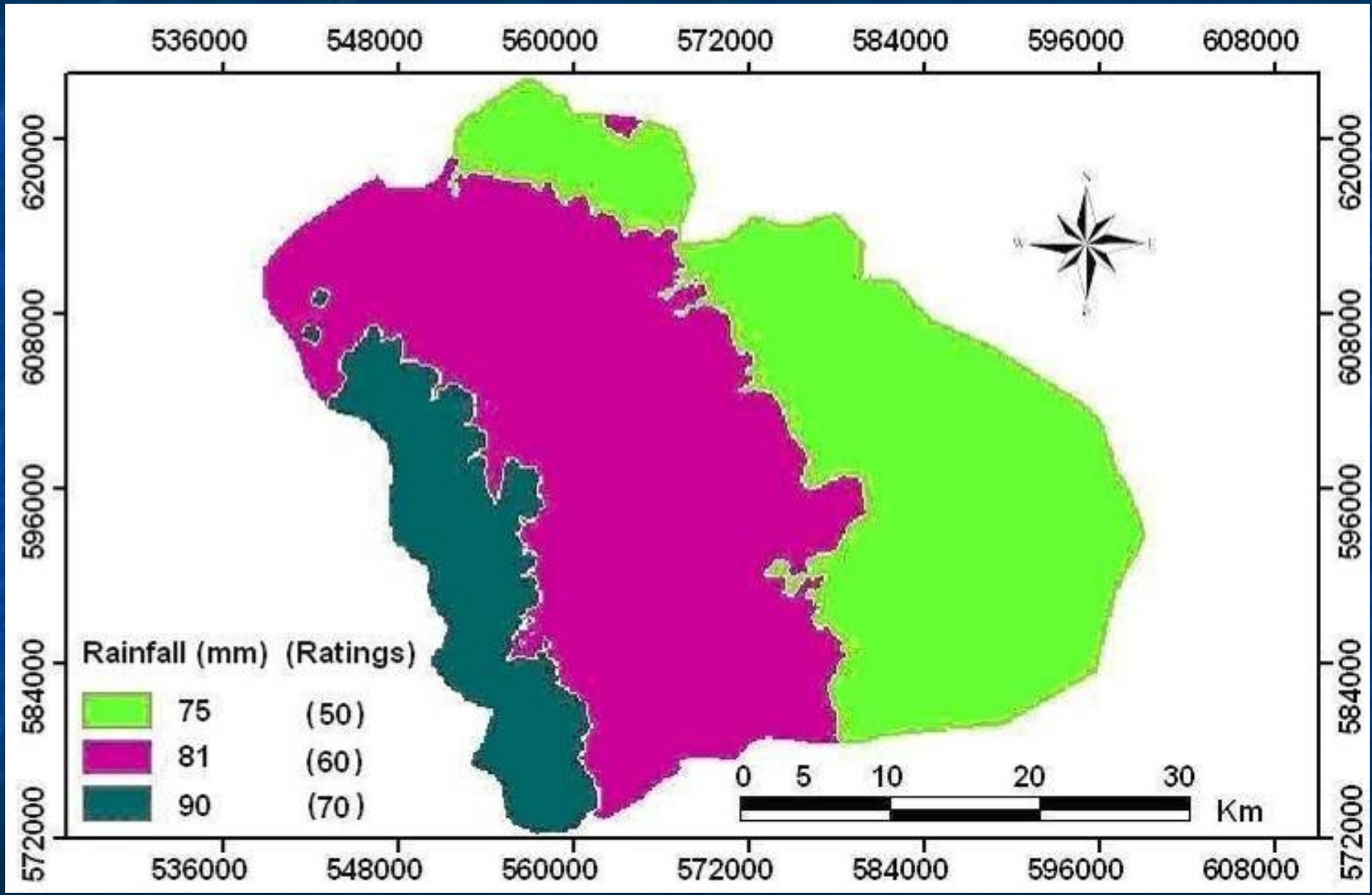
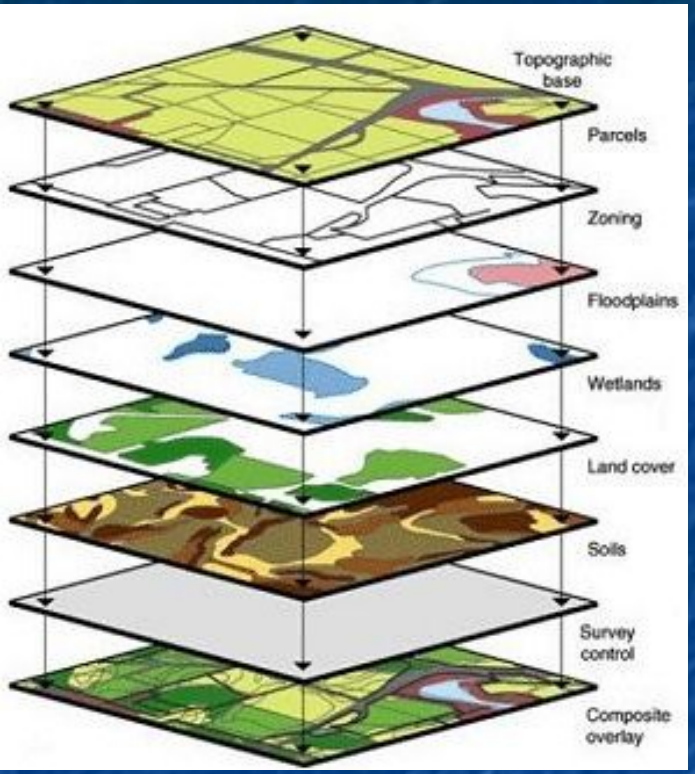
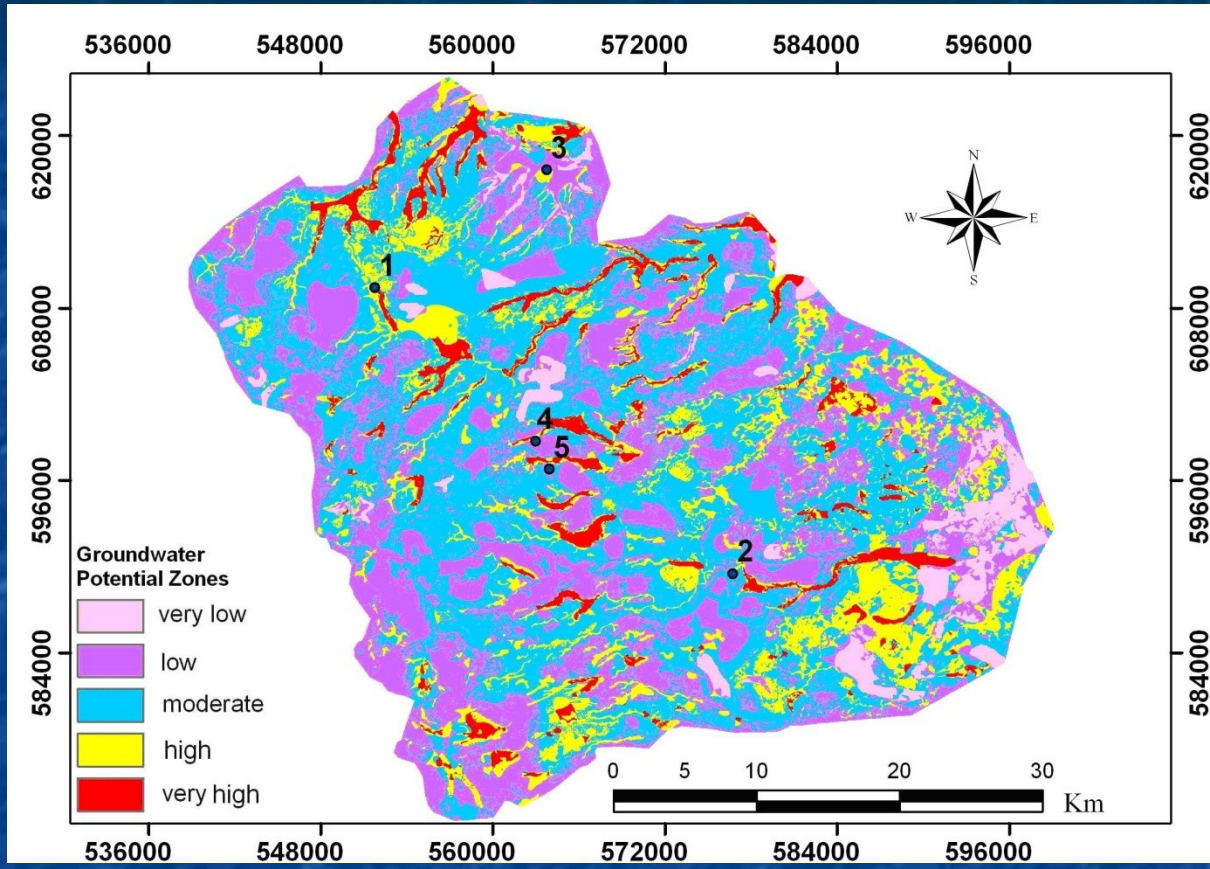
596000
608000
620000
572000
584000
596000
608000
620000
Lithology (Ratings)
5
25
40
70
N
W
E
S
0 5 10 20 30
Km

8. Rainfall


536000
548000
560000
572000
584000
596000
608000
620000
572000
Rainfall (mm) (Ratings)
75 (50)
81 (60)
90 (70)
0 5 10 20 30
Km

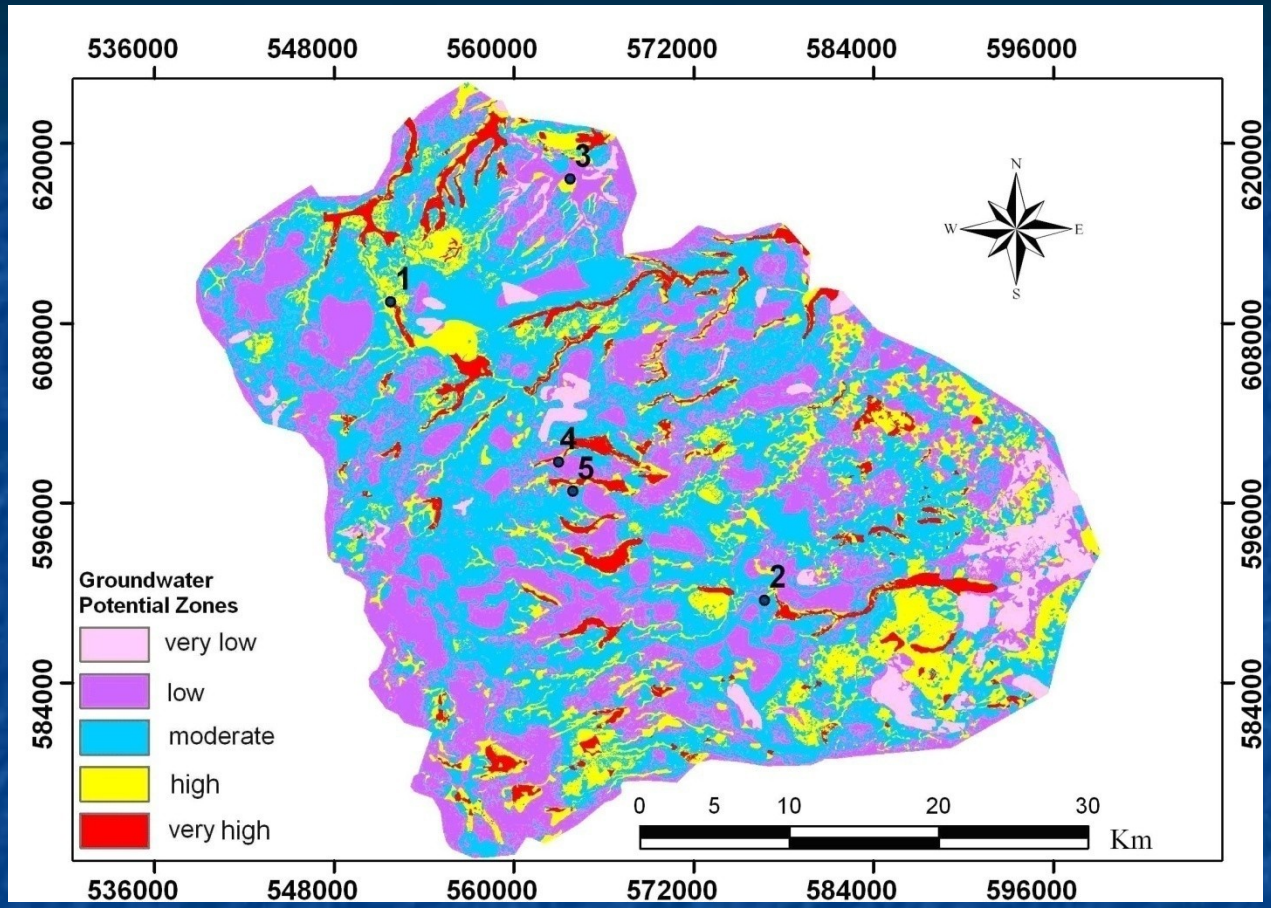
Groundwater Potential Model (GPM)





GPM Potential Class	Very Low	Low	Moderate	High	Very High
Area %	1.85	6.85	76.35	12.75	2.2

Model Validation



Well No.	No.1	No.2	No.3	No.4	No.5
Index Value	52.05	44.84	30.12	37.2	33.73

Sensitivity Analysis of GPM

1. map removal sensitivity analysis.

$$V = \frac{P - P'}{P} \times 100$$

Variation index of the excluded parameter

Variation index parameter	E	L	G	LD	R	SL	S	D
Min	13.23	11.82	13.05	13.50	8.88	10.39	13.10	11.93
Max	61.29	37.51	49.96	60.37	56.49	58.30	60.55	50.40
Mean	34.71	21.41	30.78	34.24	30.12	31.96	34.24	29.71

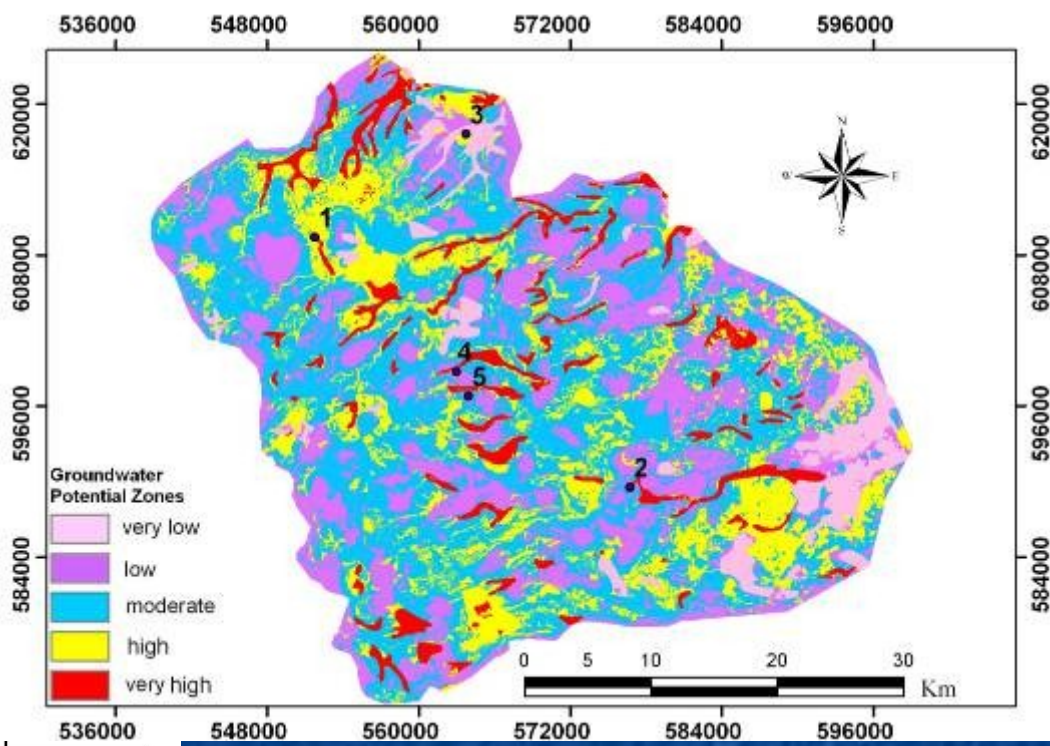
2. single parameter sensitivity analysis.

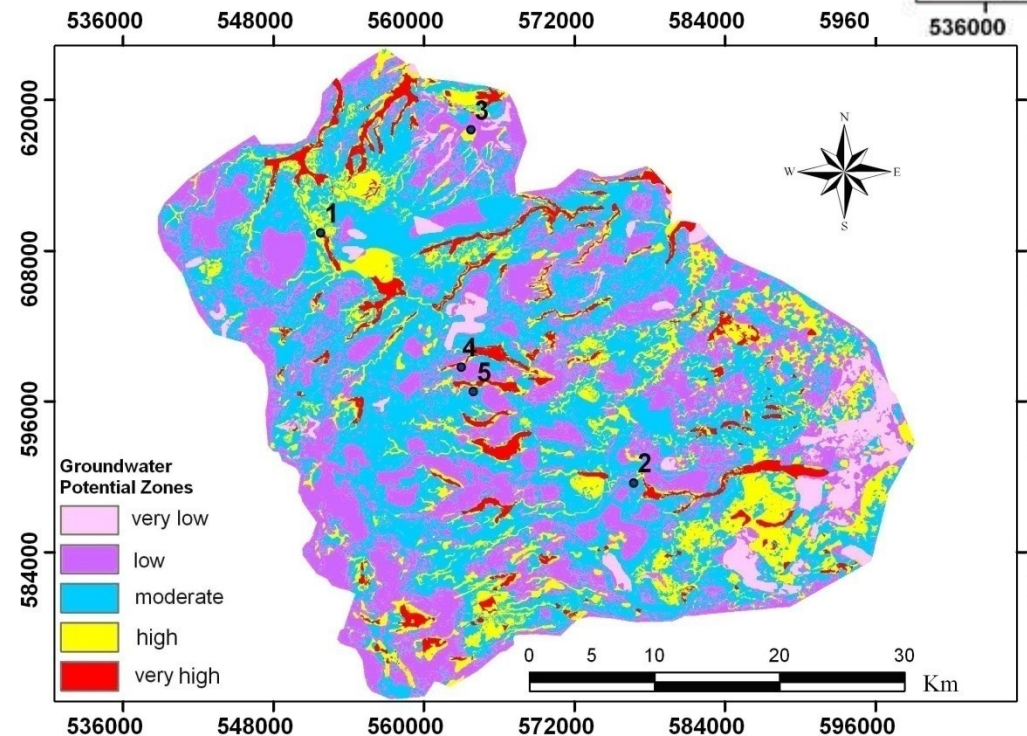
$$W = \frac{XwXs}{P} \times 100$$

Statistical analysis of the effective weights

	E	L	G	LD	R	SL	S	D
Theoretical weight (%)	1.56	34.87	19.17	2.58	9.05	9.05	4.55	19.17
Effective Weight Parameter	1.75	38.78	12.48	3.11	15.12	9.76	3.11	15.92

GPM-effective weights

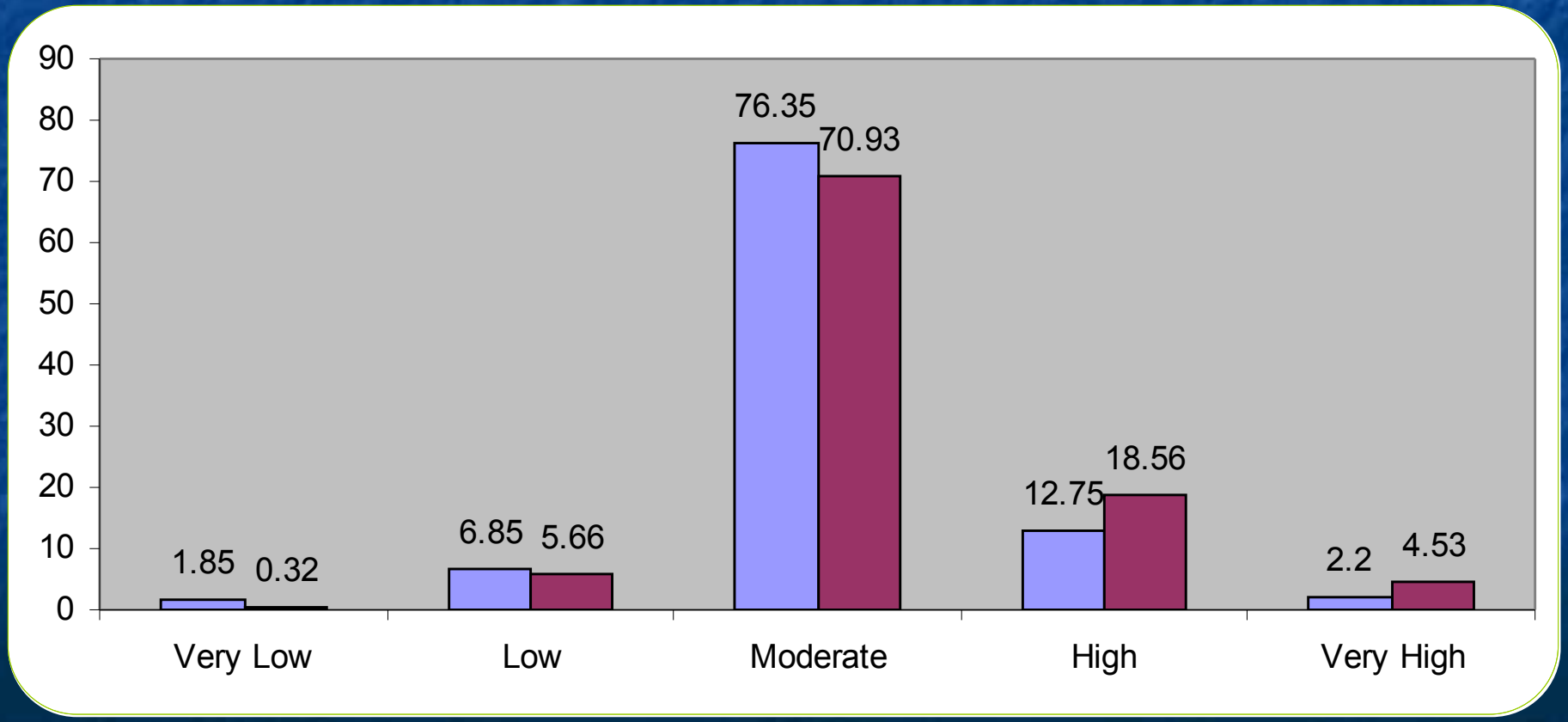




GPM-theoretical weights

GPM classes

Theoretical weights vs Effective weights



CONCLUSIONS

1. **Remote sensing images** were very important input to groundwater exploration

   -the aridity and sparseness of vegetation in the study area

   -mapping of drainage from satellite imagery is more effective than the automated derivation by the GIS software

2. Most of the **very high potential areas** represented **stream channels and wadi sediments**

3. Most of the promising areas are found below 800 m in elevation

4. Sensitivity analysis indicates that all parameters are significant but the most effective parameters : lineaments density, geomorphology, drainage density and annual rainfall

5. Field data were valuable in validating the GPM output.

6. The model identified several locations suitable for further field geophysical investigation

THANK YOU