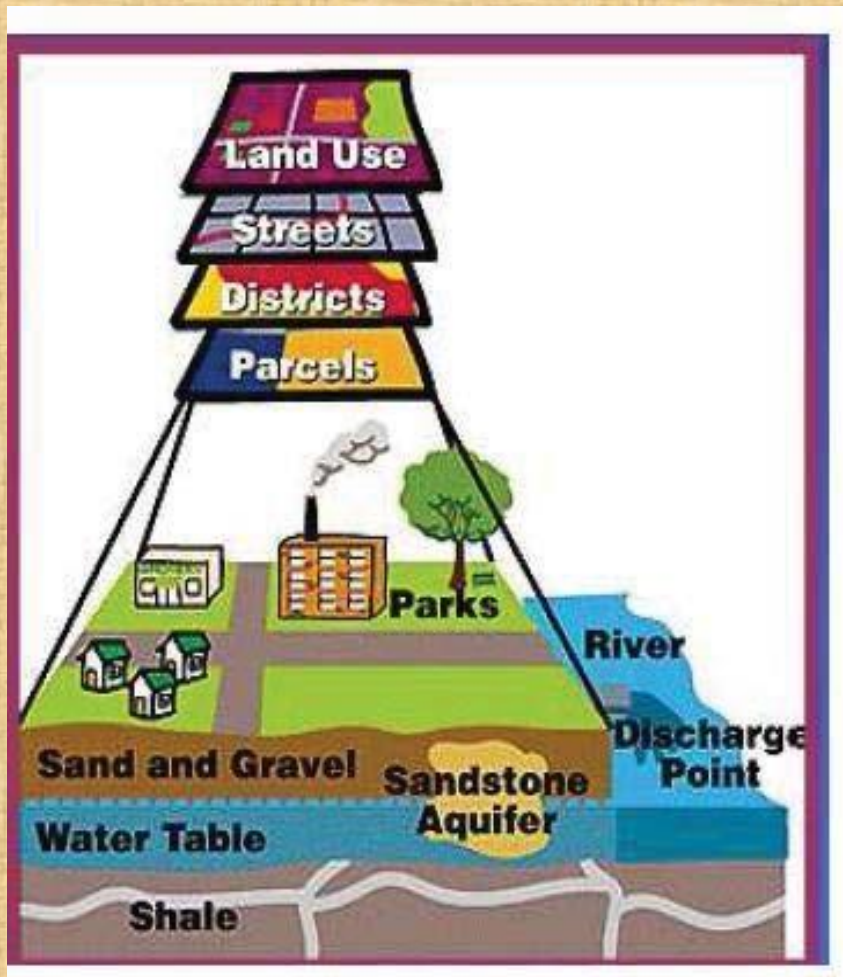


1. Introduction to GIS

What are Geographical Information Systems ?

- A geographical Information system is a computer system is a computer based tool to capture, manipulate, process and to display spatial or georeferenced data.
- 'Geographic' ... Spatial data
- 'Information' ... viewed as data with added knowledge.
- 'System' ... refers to integration of user and machine for providing information to support operations, management, analysis, and decision making and result displaying.

What are Geographical Information Systems ?



- A computer system for
 - collecting,
 - storing,
 - manipulating,
 - analyzing,
 - displaying and
 - queryinggeographically related information.

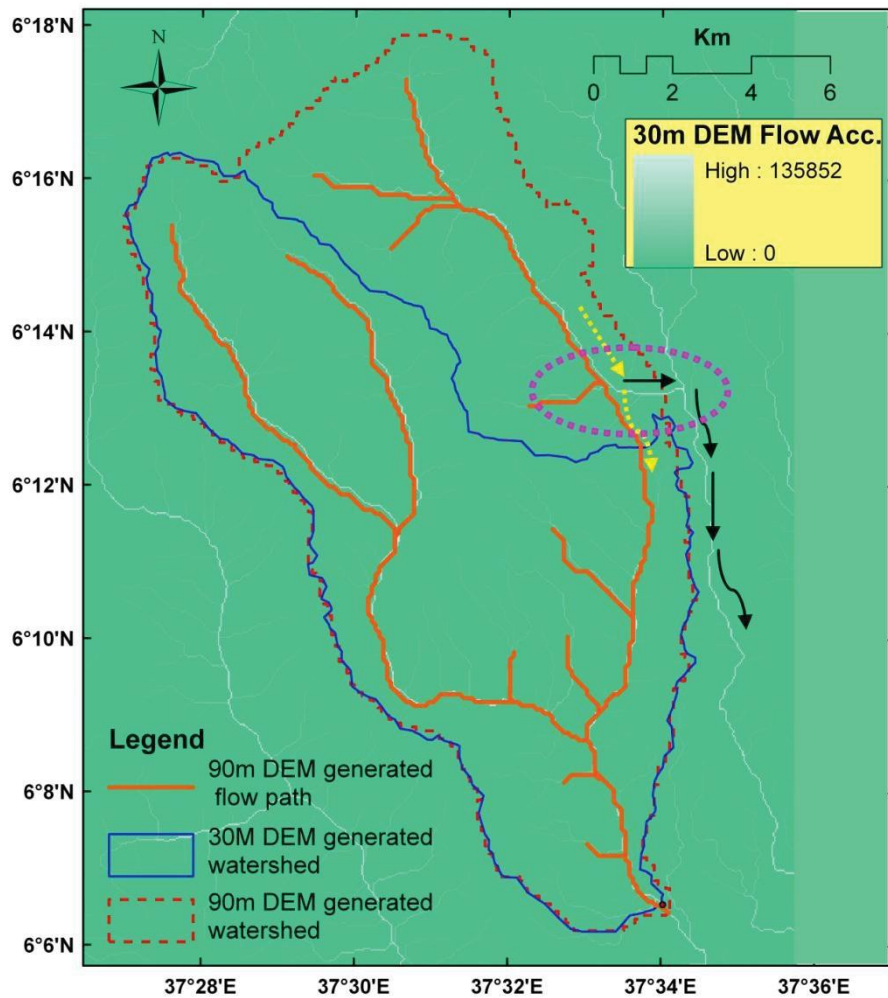
What are Geographical Information Systems ?

- GIS can be seen as a system of hardware, software and procedures designed to solve complex planning and management problems.
- A Geographic Information System uses geographically referenced or spatial data as well as non-spatial data and includes operations which support spatial analysis and the connection between the elements of the system (geography), e.g. location, proximity, spatial distribution.
- Although many other computer programs can use spatial data (e.g. AutoCAD and statistics packages), GIS includes additional ability to perform spatial operations.

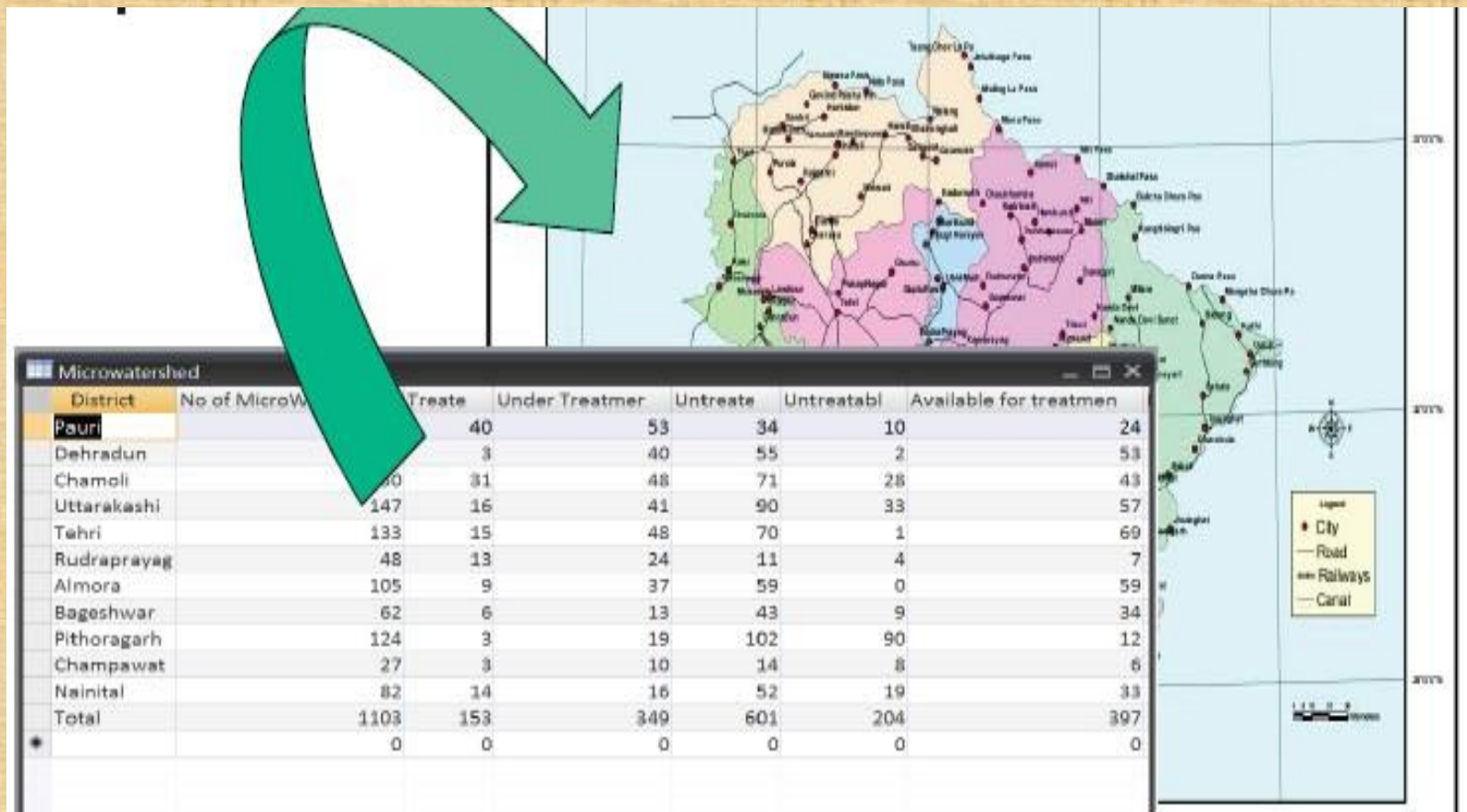
Databases: Not so easy to interpret.

District	No of MicroWatershe	Treat	Under Treatmer	Untreat	Untreatabl	Available for treatmen
Pauri	127	40	53	34	10	24
Dehradun	98	3	40	55	2	53
Chamoli	150	31	48	71	28	43
Uttarakashi	147	16	41	90	33	57
Tehri	133	15	48	70	1	69
Rudraprayag	48	13	24	11	4	7
Almora	105	9	37	59	0	59
Bageshwar	62	6	13	43	9	34
Pithoragarh	124	3	19	102	90	12
Champawat	27	3	10	14	8	6
Nainital	82	14	16	52	19	33
Total	1103	153	349	601	204	397
*	0	0	0	0	0	0

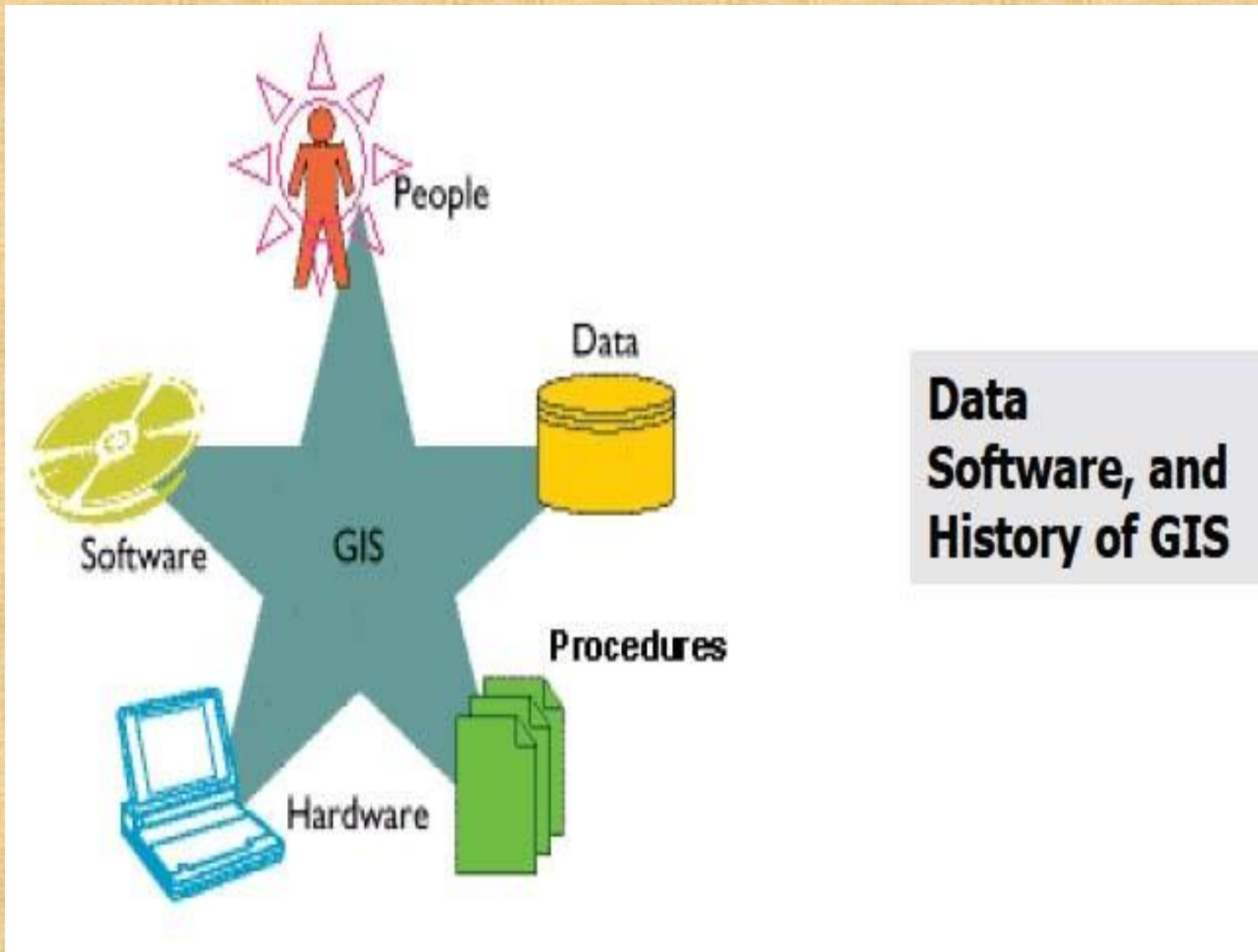
Visualization- A picture is worth thousand words !



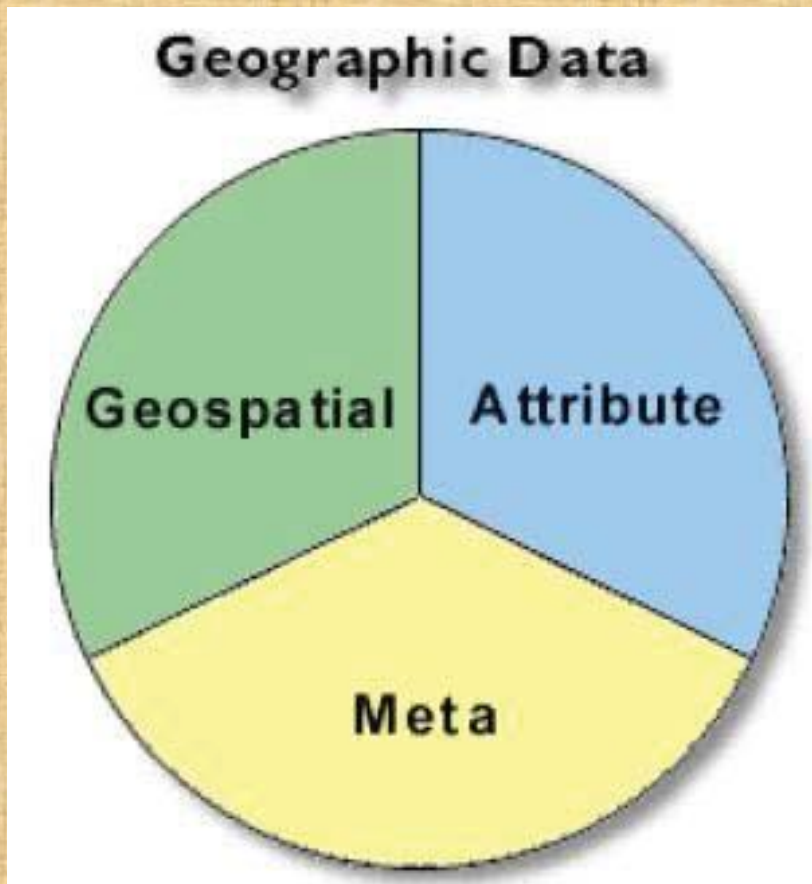
GIS connects Graphics to Data



Components of GIS



Data



- **Geospatial data** tells you where it is and **attribute data** tells you what it is. **Metadata** describes both geospatial and attribute data.

What is Geospatial data

- Geospatial data identifies the **geographic location** and **characteristics** of natural features, manmade features, or boundaries on the earth. For example: river, street, campus and state boundaries.
- Before GIS, geospatial data is expressed and stored in a paper map.
- With GIS, geospatial data is stored in digital format. **Geospatial data** refers to **feature location**, and **attribute data** used to describe those features or characteristics.
- Attribute data is stored in a table called attribute table, which links to the feature location.

How do GIS Data are Collected ?



And many more such as
weather station observations
water meter readings,
sampler analysis results,
daily sale amounts
census results

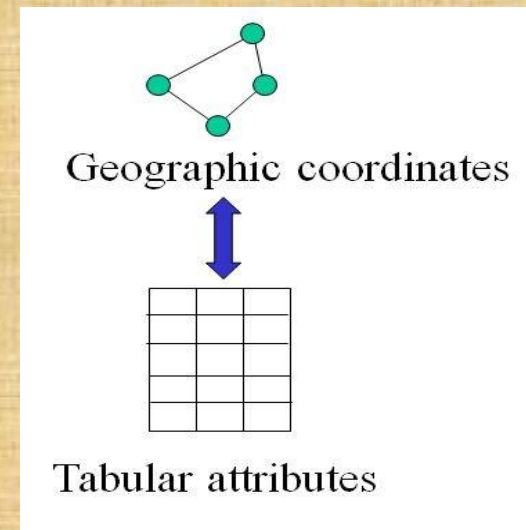
.....

- Geodatabases & Geographic data models

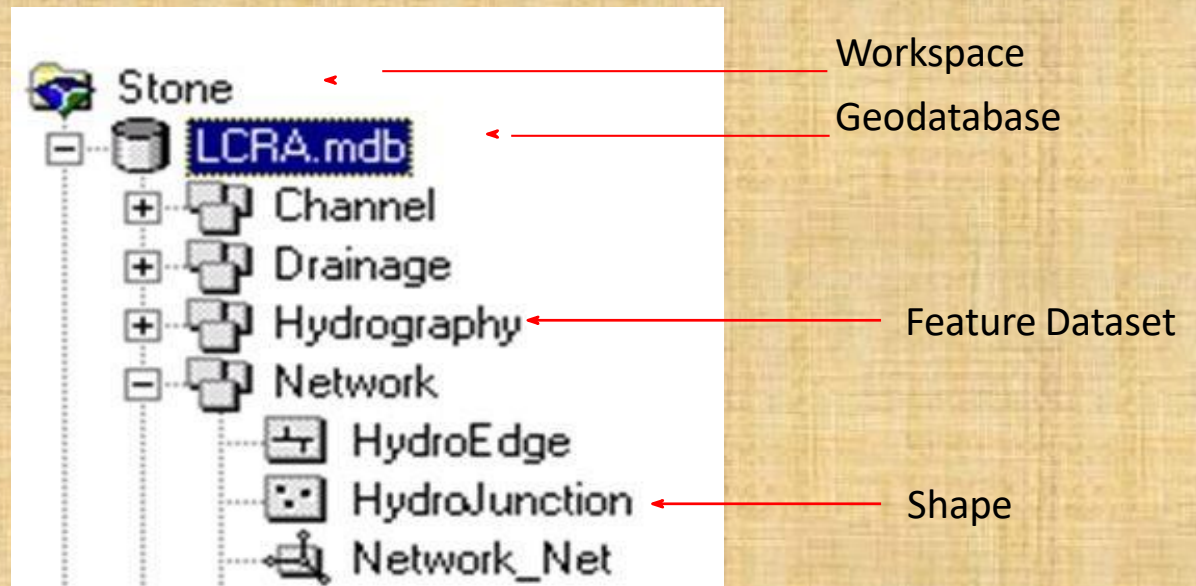
A **geographic data model** is a structure for organizing geospatial data so that it can be easily stored and retrieved: **Vector or Raster**



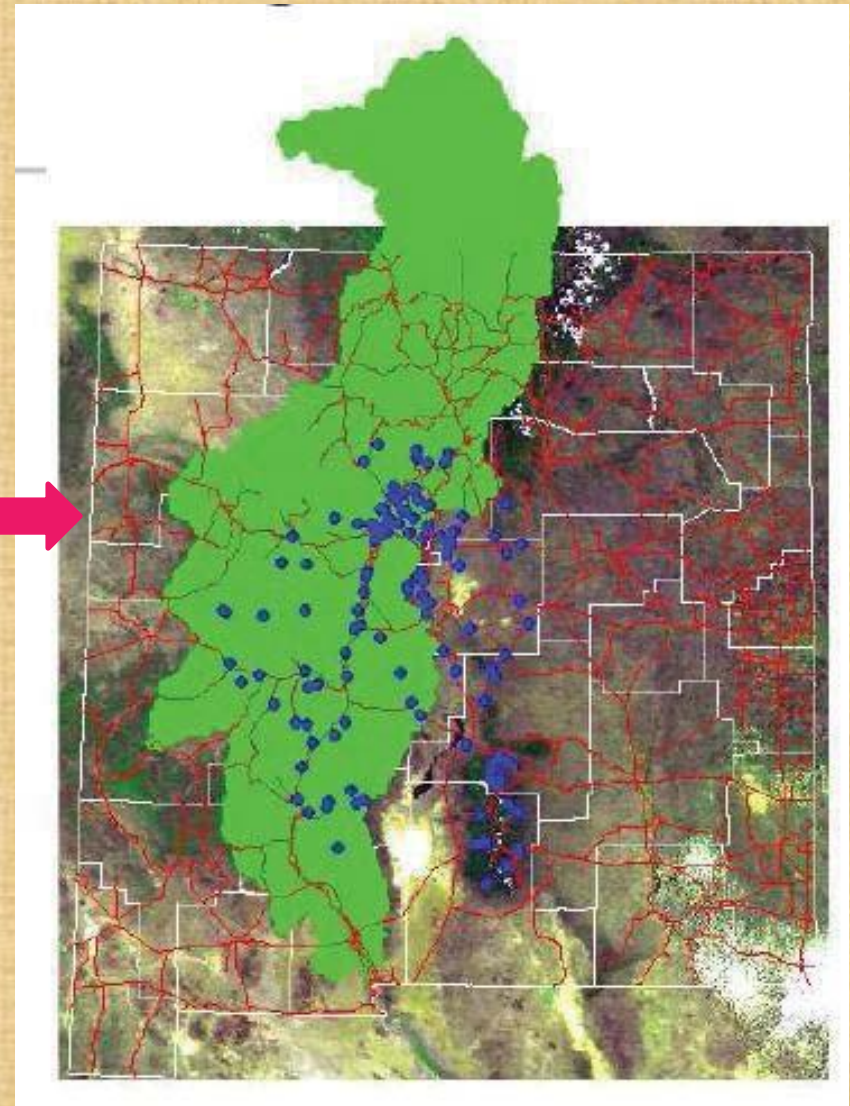
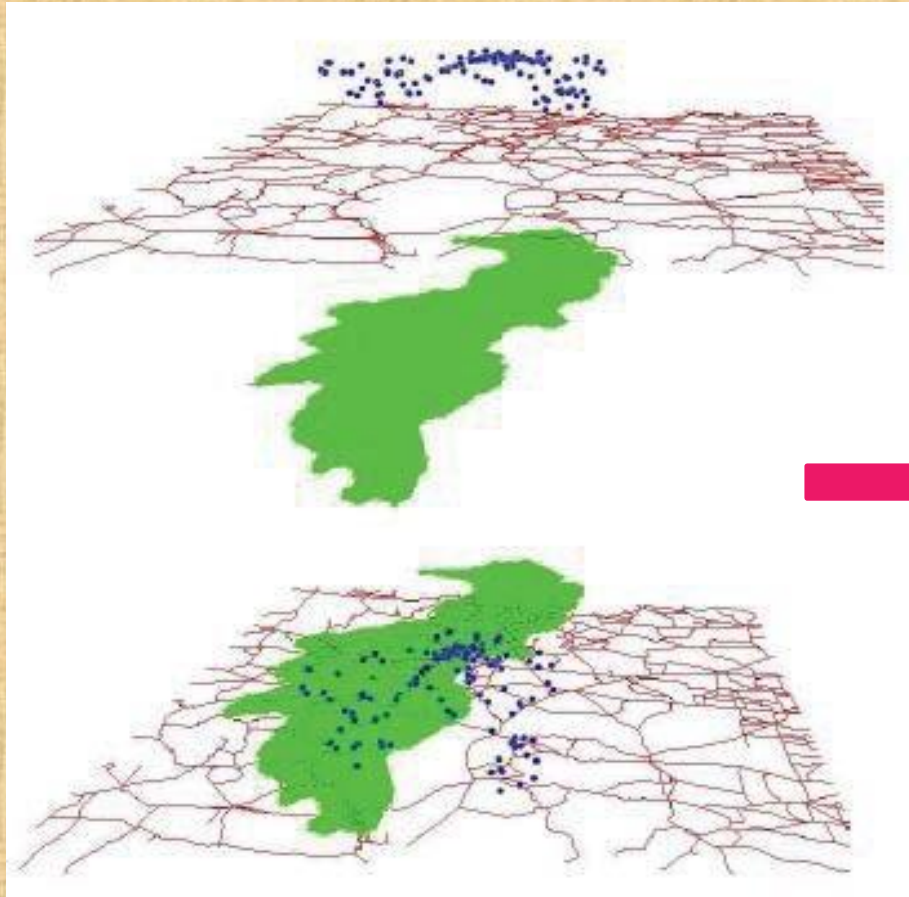
The **geodatabase** is a “container” used to hold a collection of datasets



- File Geodatabase (.gdb)
- Personal Geodatabase (.mdb)



Power of GIS - integration



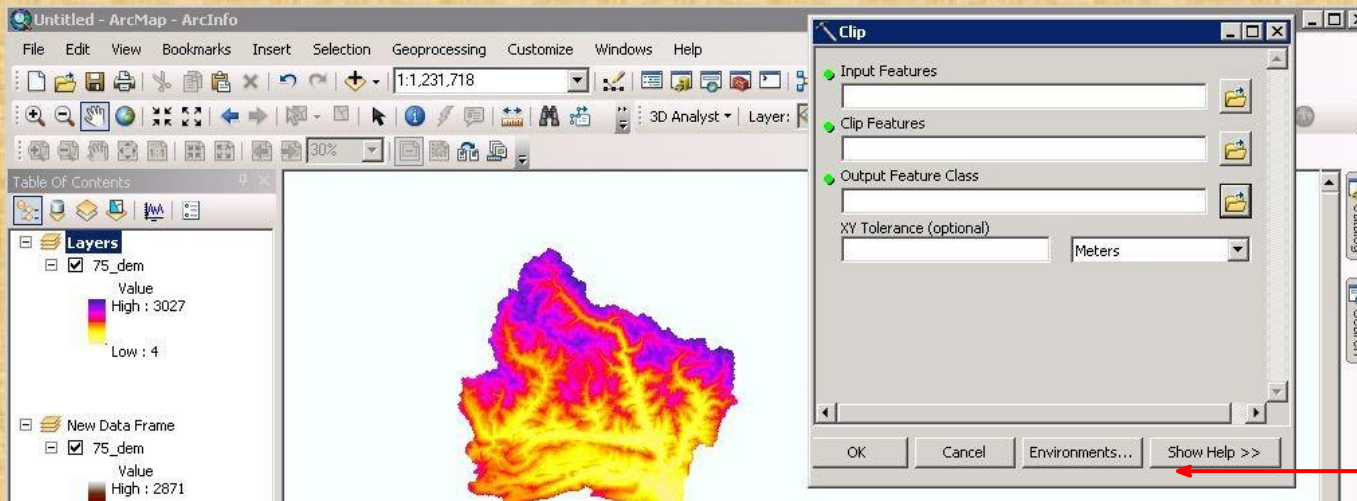
Why GIS ?

- Provides powerful tools for
 - data process, analysis, and visualization
 - data management and retrieval
- One of the fastest growing high-tech career fields

GIS- Applications

- **Agriculture**
- **Archaeology**
- **Business**
- **Environment**
- **Geology**
- **Health**
- **Hydrology**
- **Land Information System**
- **Military**
- **Natural Hazard Management**
- **Natural Resource Management**
- **Urban Planning**
- **Many more**

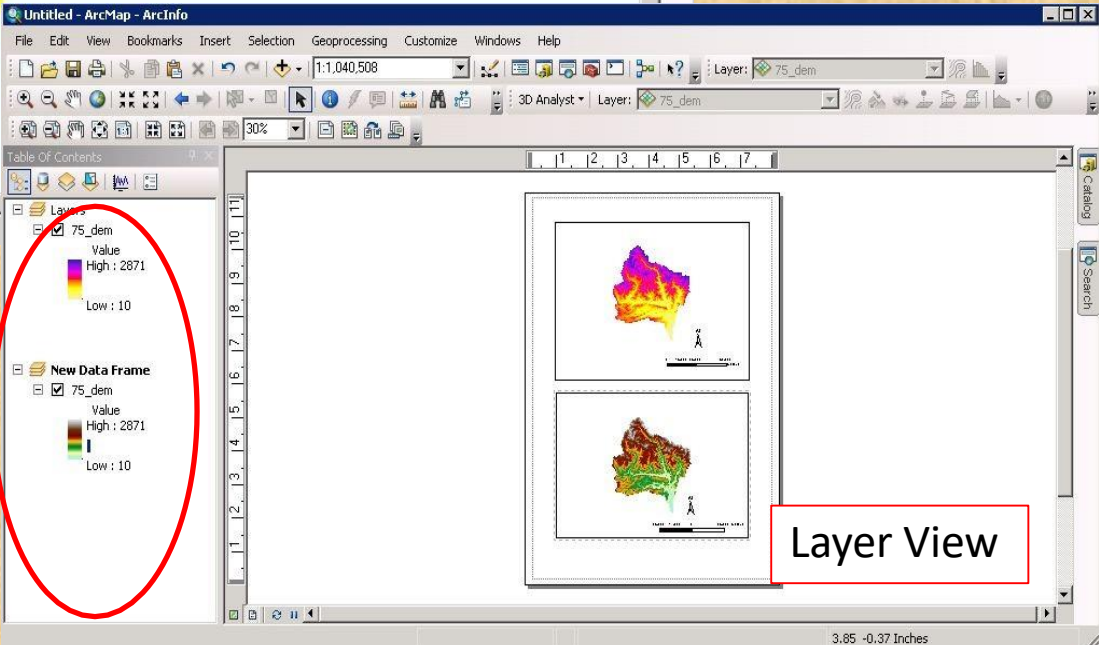
- ArcMap



Analyze Data
(tool for
geoprocessing)

Data View

View and Edit Data

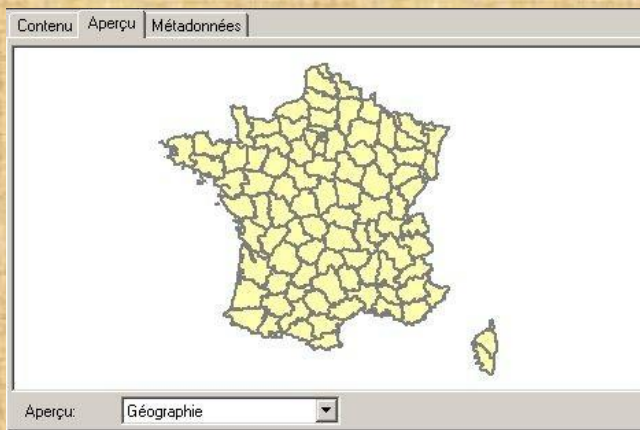


Layer View



- **ArcCatalog**
- Data & Metadata management
 - Creation and modify the attribute table
 - Connect a folder

ArcCatalog can provide different views:



Geographical View

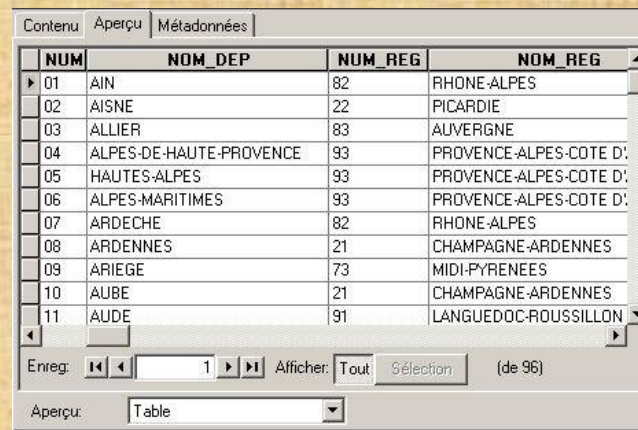
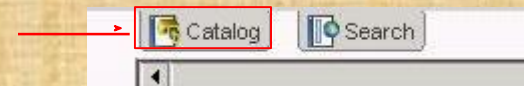


Table View

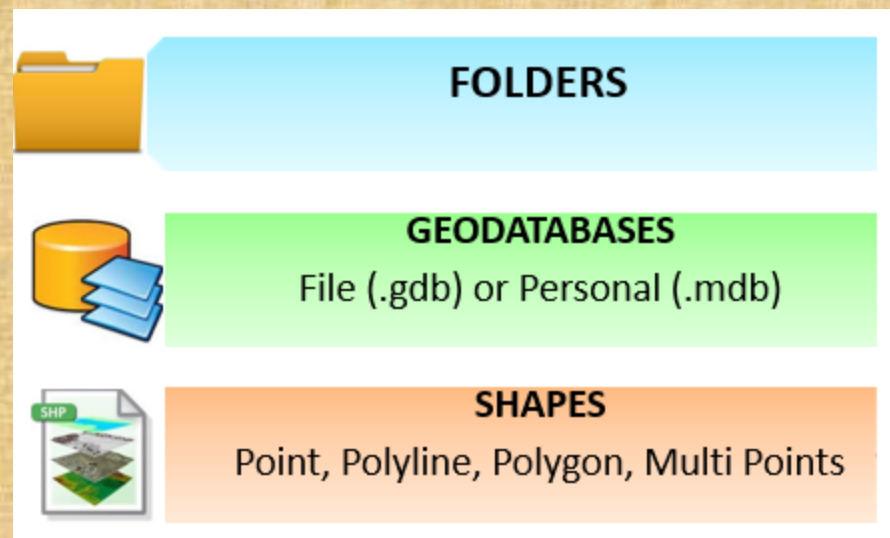
It is possible to use **ArcCatalog** directly within ArcMap on the right border



- **ArcCatalog:** you can connect a folder and create new entities like folder, geodatabase, shape ...



To create new entities you can use the File Menu from ArcCatalog or the ArcCatalog window in ArcMap



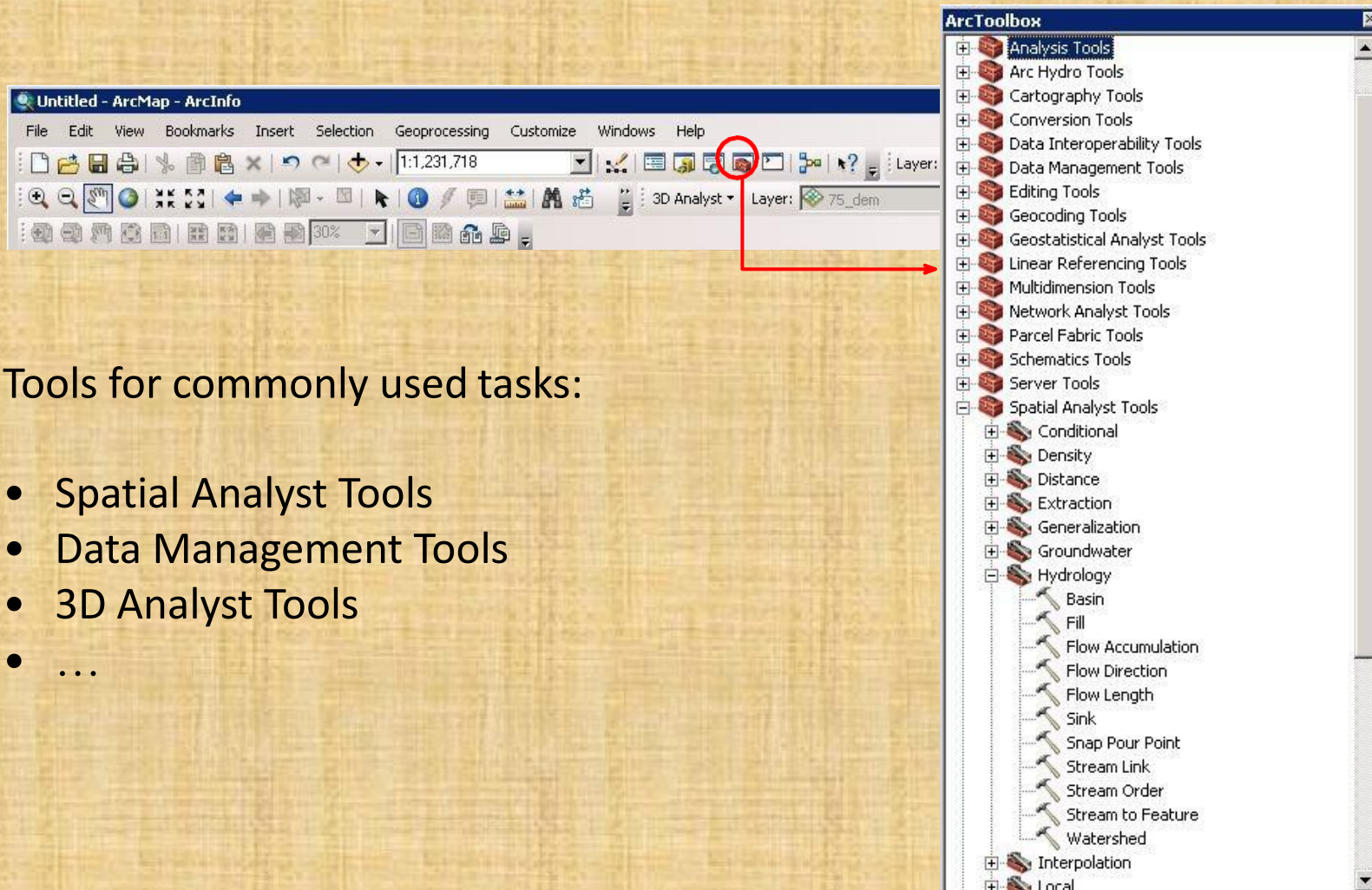
Don't forget to define the Coordinate System

You can find some information by clicking on the following link:

[http://resources.arcgis.com/en/help/main/10.1/index.html#/An overview of spatial references/003n0000001t000000/](http://resources.arcgis.com/en/help/main/10.1/index.html#/An%20overview%20of%20spatial%20references/003n0000001t000000/)

[html#/An overview of spatial references/003n0000001t000000/](http://resources.arcgis.com/en/help/main/10.1/index.html#/An%20overview%20of%20spatial%20references/003n0000001t000000/)

- **ArcToolbox:** window which is the central place where you find, manage, and execute geoprocessing tools



Tools for commonly used tasks:

- Spatial Analyst Tools
- Data Management Tools
- 3D Analyst Tools
- ...

2. Data models in GIS

- Raster data model
- Vector data model
- Triangulated irregular network model (TIN)
- Digital elevation model (DEM)

Data types in GIS

The data in a GIS can be classified into two main categories

1. Spatial data

Describes the absolute and relative location of geographic features

2. Attribute data or non spatial data

Describes characteristics of the spatial features. These characteristics can be quantitative and/or qualitative in nature.

Discrete and continuous data

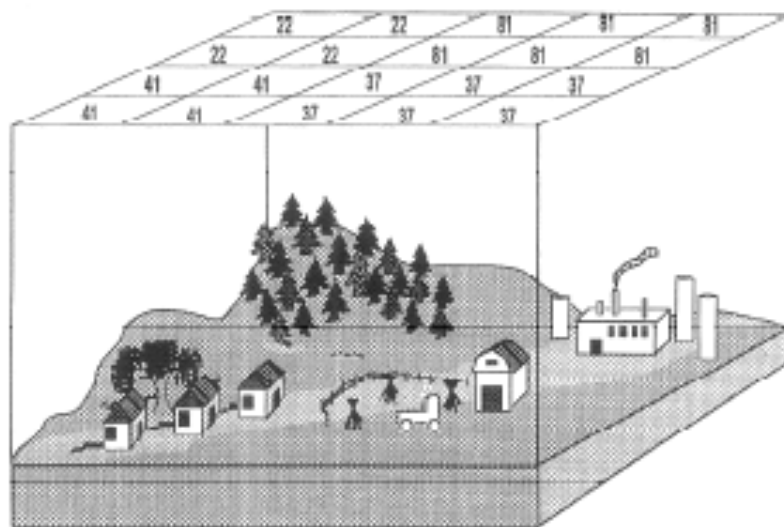
There are two basic types of measures of the geographic landscape, but in different ways.

Discrete data are distinct features that have define boundaries and identities. They constitute separate entities: each is spatially well defined features class: e.g. Land use, wells, roads,....

Continuous data does not have defined borders or distinctive values. Instead, a transition from one measure to another is implied. eg temperature mapping, elevation (DEM), aspect

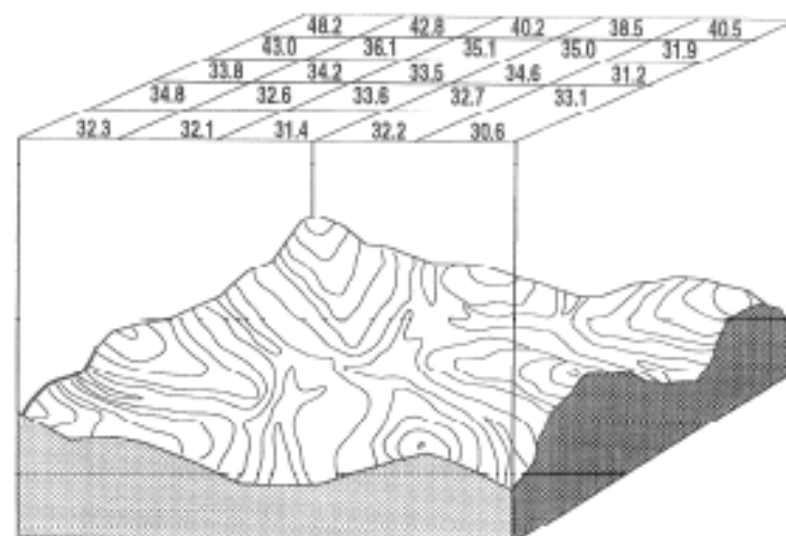
Discrete versus continuous data

**Discrete data
(integer grids)**



**Land use
Zoning
Vegetation type
Roads
Wells**

**Continuous data
(floating point grids)**

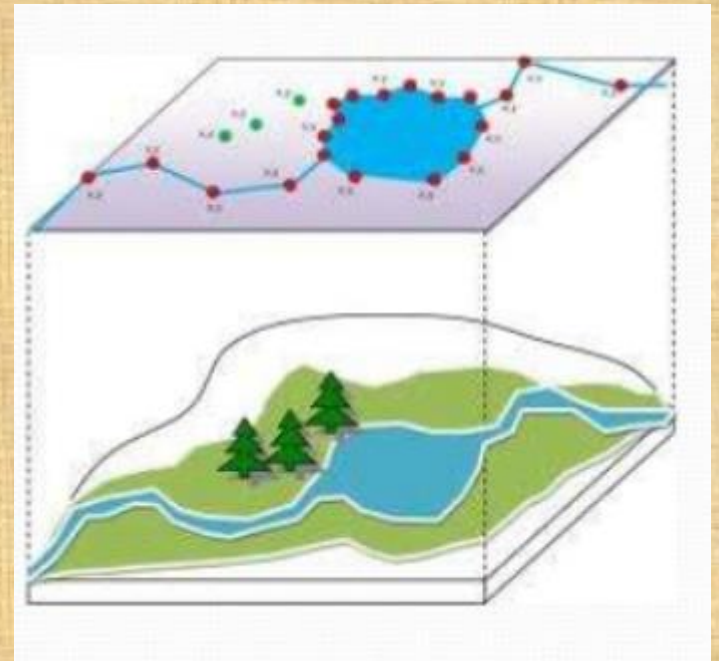


**Elevation
Aspect
Pollution levels
Rainfall**

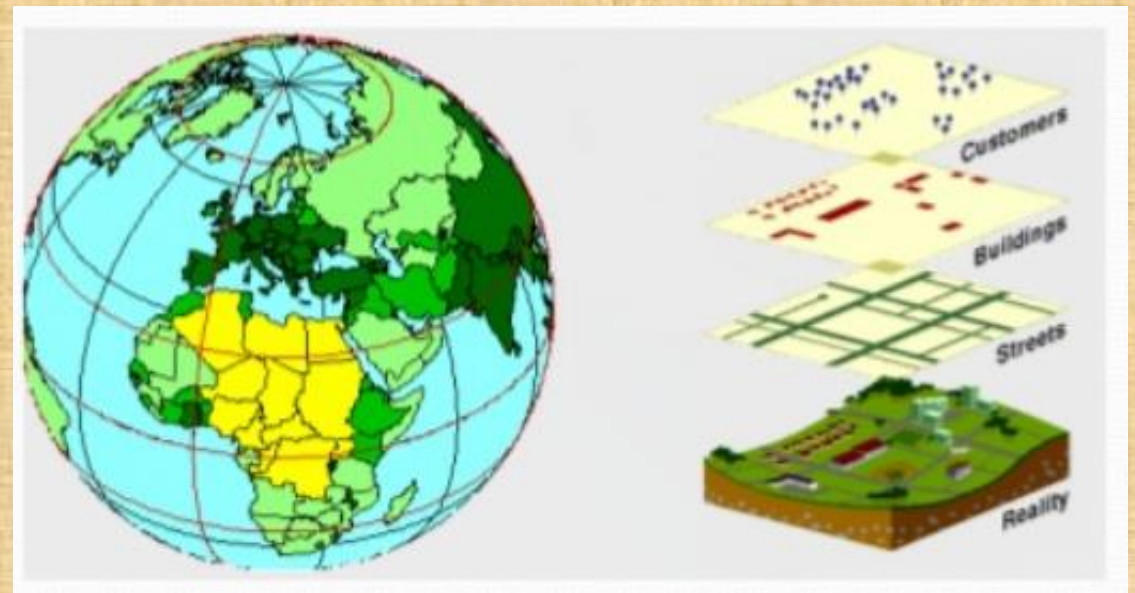
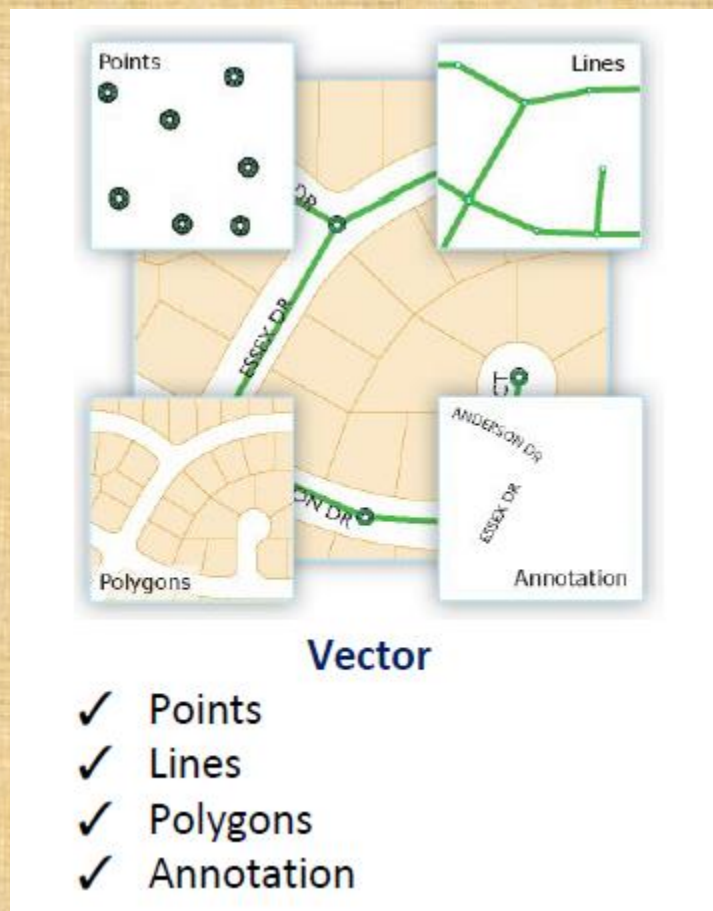
GIS presents two kind of geographic data models: **Vector & Raster**

A. Vector

- Vectors are graphical objects that have geometrical primitives such as points, lines and polygons (areas corresponding to discrete objects with name or code of attributes).
- A vector refers to a geometrical space which has a precise direction, length and shape
- Points, lines and polygons can be defined by the coordinate geometry.

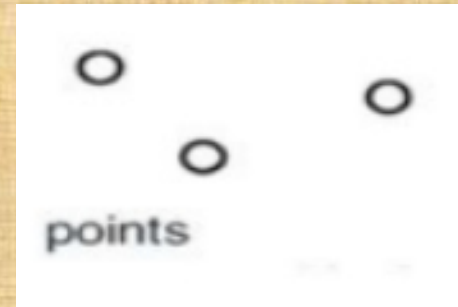


A vector spatial data model uses two-dimensional cartesian (X,Y) coordinate system to store the shape of a spatial entity



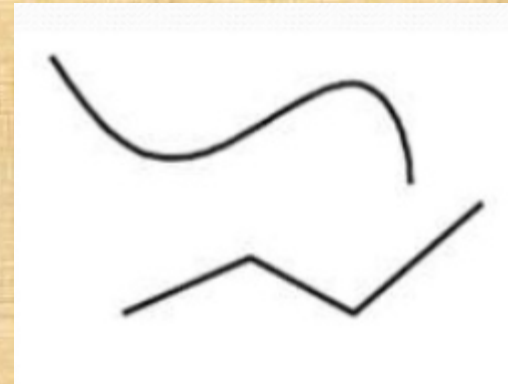
Points

- A point is a 0-dimensional object and has only the property of location (X,Y)
- Points can be used to model features such as a well, building, power house, pole, sample location etc...
- Other names for a point are vertex, node, 0-cell



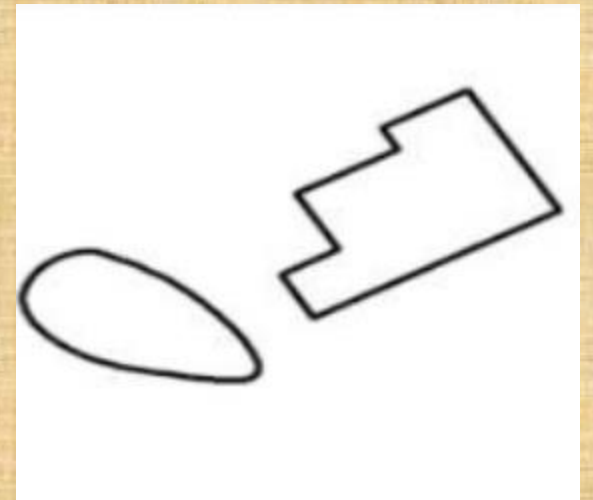
Lines

- A line is a one-dimensional object that has the property of length
- Lines can be used to represent road, streams, faults, dikes, boundary, contacts etc
- Lines are also called an edge, link, chain, arc, 1-cell



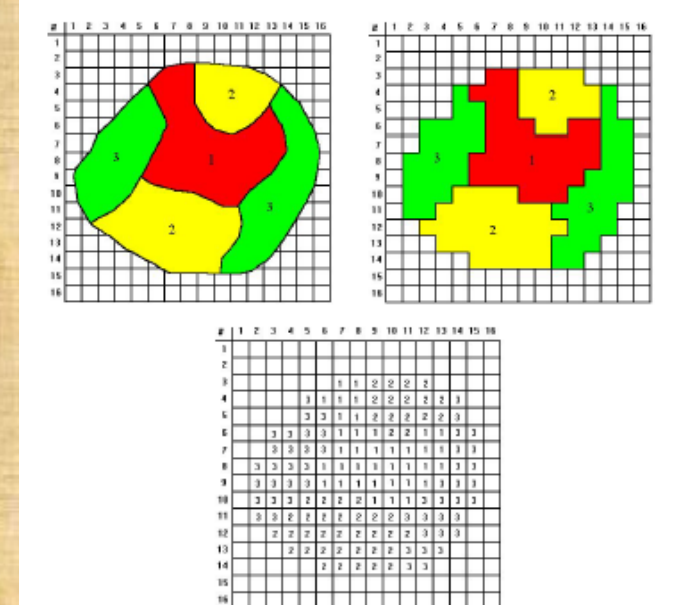
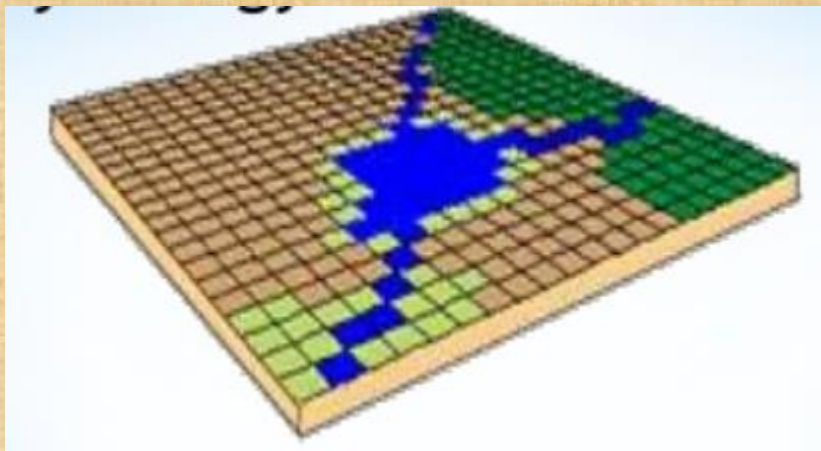
Polygon

- Polygon features are made of one or more lines that encloses an area
- A polygon is two-dimensional object with properties of area and perimeter represented by a closed sequence of lines
- A polygon can represent a city, geologic information, dike, river, etc



B. Raster

- The term raster implies a regularly spaced grid.
- An element of a grid cell is called a pixel (picture cell). Raster data consists of rows and columns of cells. Every location is given in two dimensional image coordinates; pixel number and line number, which contains a single value of attributes. Raster data can represent a multiplicity of things including:
 - Visual images (that is colour)
 - Discrete value such as land use
 - Continuous value, rainfall
 - Null values if no data is available



Raster: consists of a matrix of cells (or pixels) organized into rows and columns (or a grid)

Cell size of raster data

Smaller cell size

- Higher resolution
- Higher feature spatial accuracy
- Slower display
- Slower processing
- Larger file size

Larger cell size

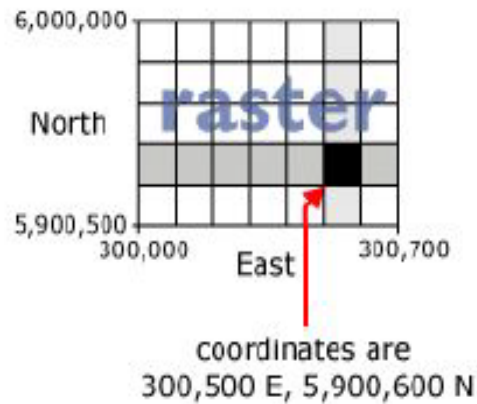
- Lower resolution
- Lower feature spatial accuracy
- Faster display
- Faster processing
- Smaller file size

Raster grid properties

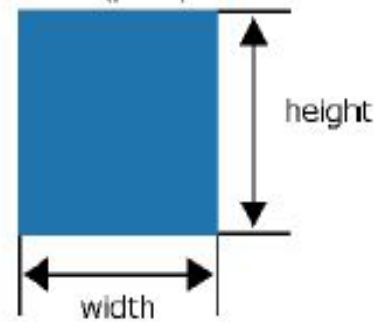
- **Grid:** contains a value representing information. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps.
- Each grid cell holds one value even if it is empty.
- A cell can hold an index standing for an attribute.
- Cell resolution is given as its size on the ground.
- Points and lines move to the center of the cell.
- Minimum line width is one cell
- Rasters are easy to read and write, and easy to draw on the screen.

Grid

UTM-Projected
Coordinate System



cell (pixel)

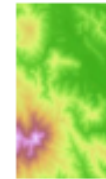


The location of each cell is defined by the row or column where it is located within the raster matrix

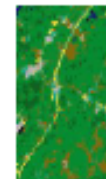
The dimension of the cells can be as large or as small as needed to represent the surface conveyed



Rasters as basemaps



Rasters as surface maps



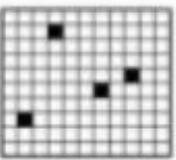

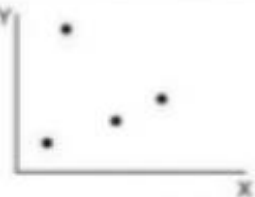
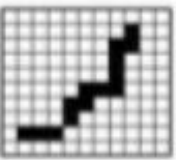


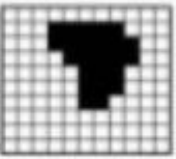

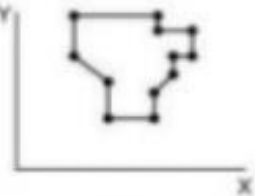
Rasters as thematic maps

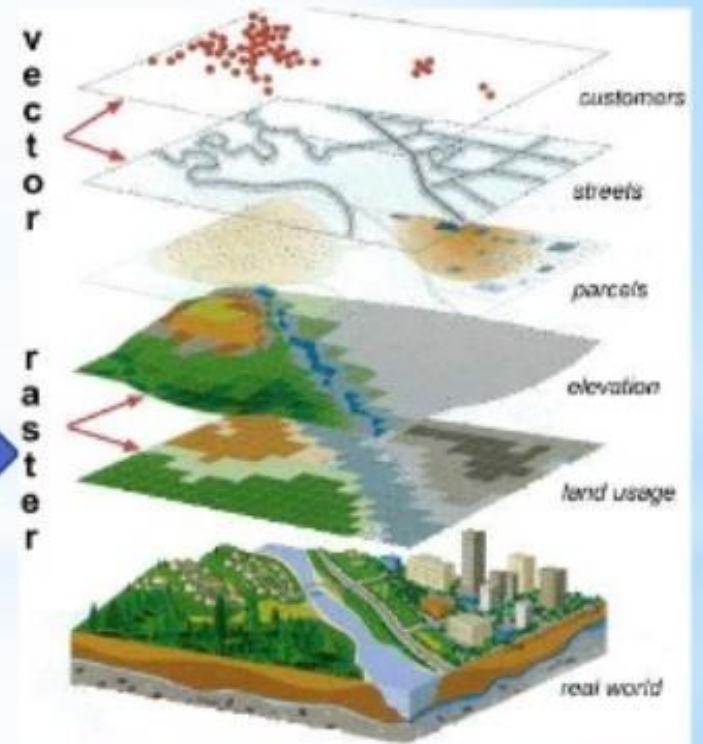


Rasters as attributes of a feature

Raster-Vector comparison

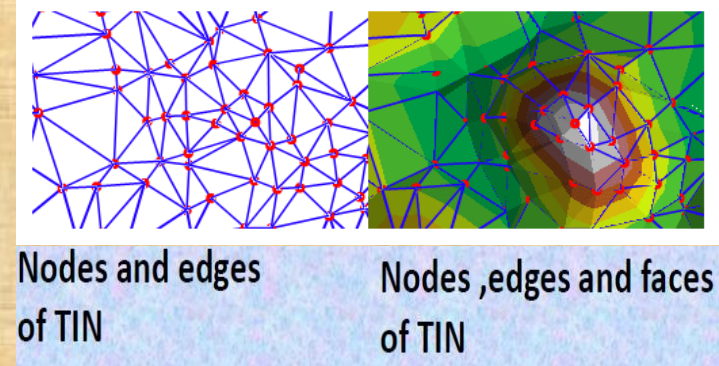
	Raster	Vector
Data collection	Rapid	Slow
Data volume	Large	Small
Graphic treatment	Average	Good
Data structure	Simple	Complex
Geometrical accuracy	Low	High
Analysis in network	Poor	Good
Area analysis	Good	Average
Generalization	Simple	Complex
Continuous phenomena	Average	Poor

The raster view of the world	Happy Valley spatial entities	The vector view of the world
	 x x Points: hotels	
	 Lines: ski lifts	
	 Areas: forest	



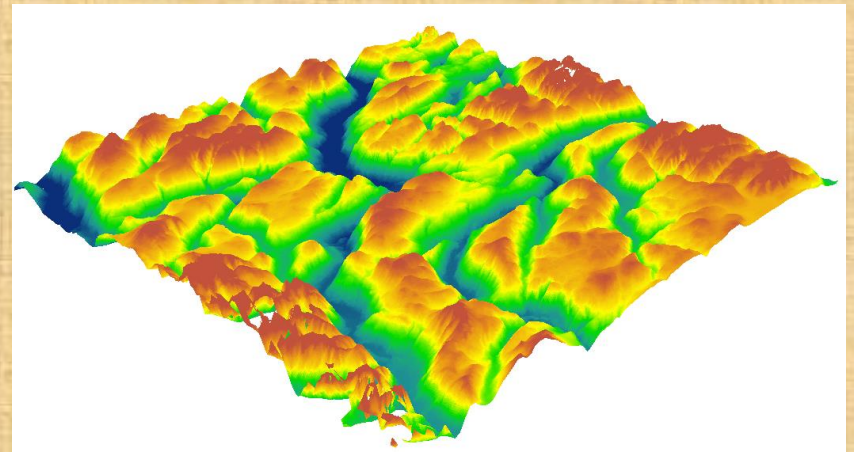
Triangulated Irregular Network (TIN)

- Datasets can be used to display and analyze surfaces. Which is a vector approach to handling a digital elevation model
- TIN's are used to interpolate surfaces using multiple triangle
- TIN's connect these points to form a set of continuous and connected triangles. The data point consists of X, Y and Z values. The final result gives users a TIN surface.



Digital Elevation Model (DEM)

- DEM is a data model which represents the surface of a terrain in 3-dimension.
- DEM can be represented as a raster or as TIN.
- The TIN DEM dataset is also referred to as a primary DEM or measured DEM.
- Raster DEM is referred to as secondary DEM or computed DEM.



USGS DATA

- DEM = Digital Elevation Model
- NED = National Elevation Dataset
- NHD = National Hydrography Dataset
- DRG = Digital Raster Graphic
- DLG = Digital Line Graph
- DOQQ = Digital Ortho Quarter Quad
- GNIS = Geographic Names Information System
- LULC = Land Use Land Cover
- NLCD = National Land Cover Data

3. Projections Coordinate Systems

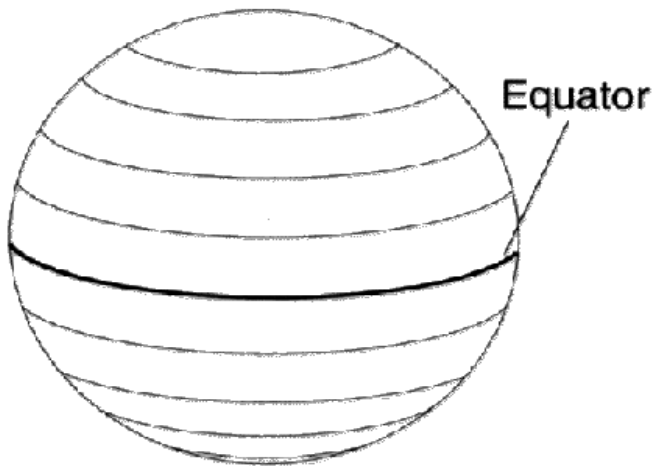
Geodesy - the shape of the earth and definition of earth datums

Map Projection - the transformation of a curved earth to a flat map

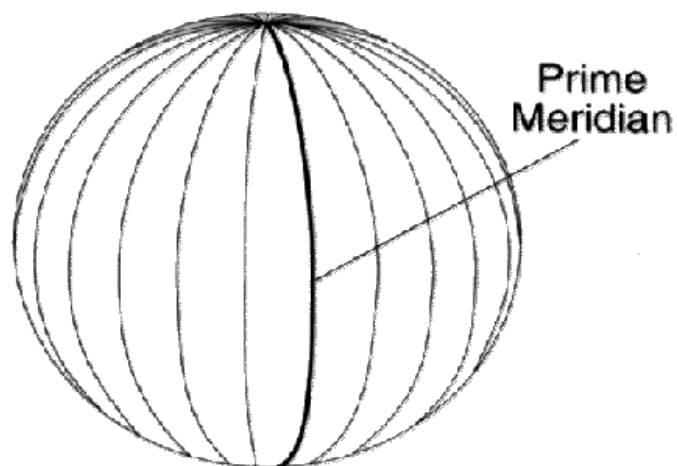
Coordinate systems - (x,y,z) coordinate systems for map data

Referencing location on the earth's surface

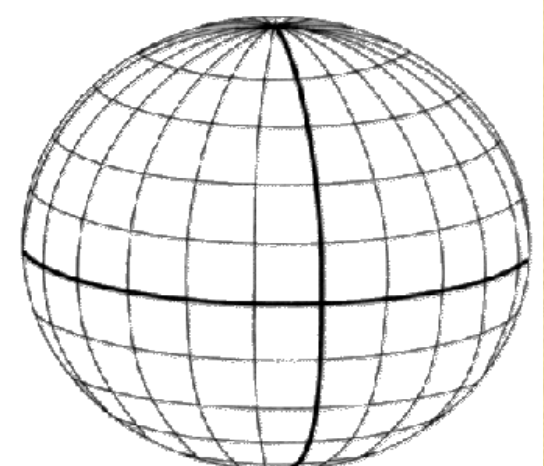
- latitude and longitude reference system
- latitude (ϕ), λ : angle from the equator to the parallel
- Longitude (λ), λ : angle from Greenwich meridian



Parallels of
Latitude



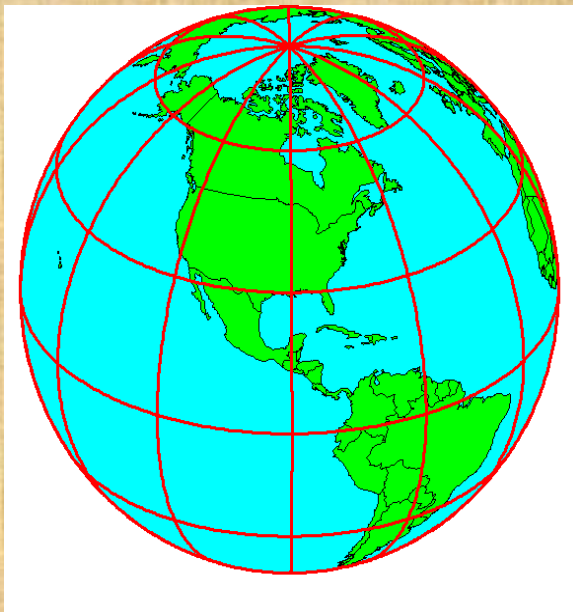
Meridians of
Longitude



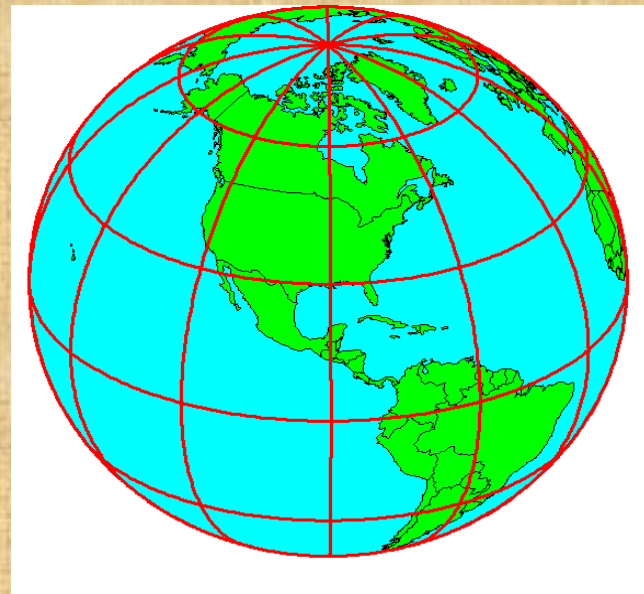
Graticular
Network

Shape of the Earth

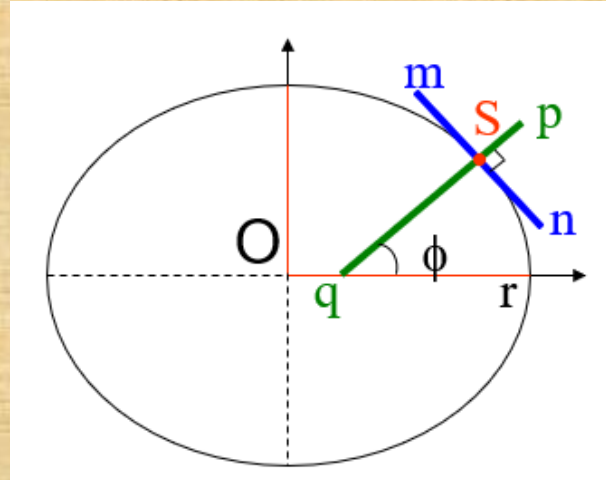
We think of the earth as a **sphere**



It is actually a **spheroid**, slightly larger in radius at the equator than at the poles



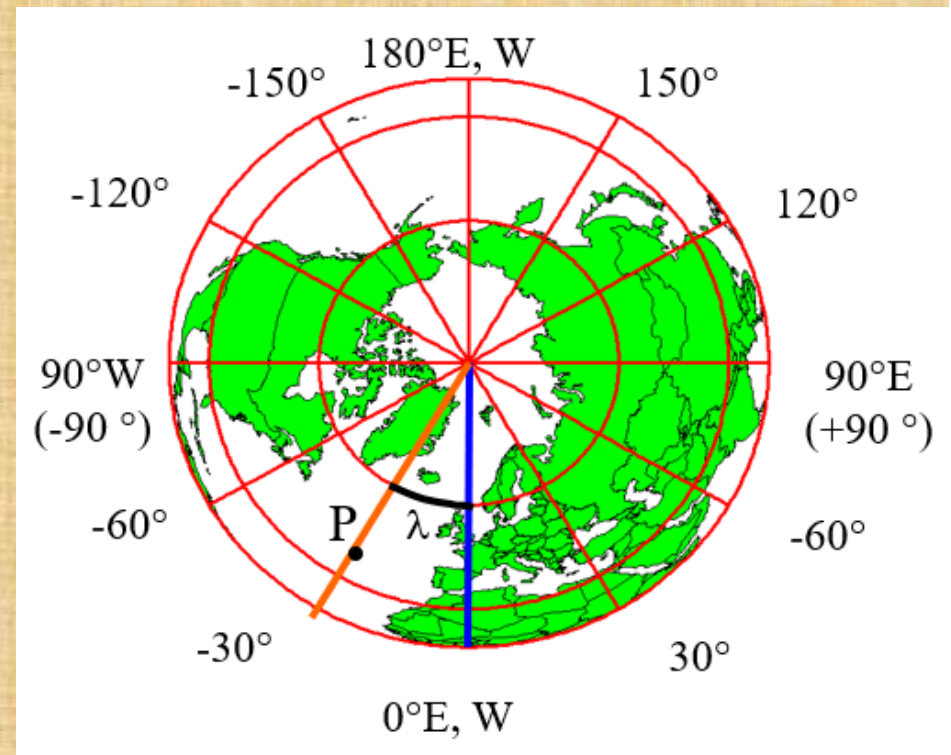
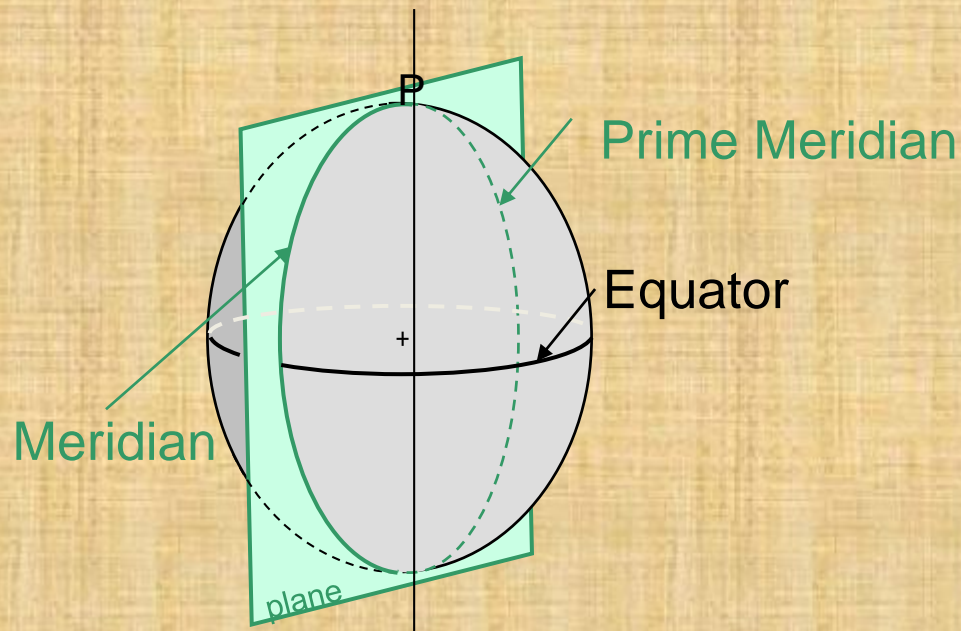
Definition of Latitude, ϕ



- (1) Take a point **S** on the surface of the ellipsoid and define there the **tangent plane, mn**
- (2) Define the line **pq** through S and **normal** to the tangent plane
- (3) **Angle pqr** which this line makes with the equatorial plane is the latitude **φ**, of point S

Definition of Longitude, λ

λ = the angle between a cutting plane on the prime meridian and the cutting plane on the meridian through the point, P



Reference Ellipsoid

Latitude (ϕ) and Longitude (λ) defined using an **ellipsoid**, an ellipse rotated about an axis

For the earth:

Major axis, $a = 6378$ km

Minor axis, $b = 6357$ km

Flattening ratio, $f = (a-b)/a$
 $\sim 1/300$

Ellipsoidal Parameters

a - semi-major axis

b - semi-minor axis

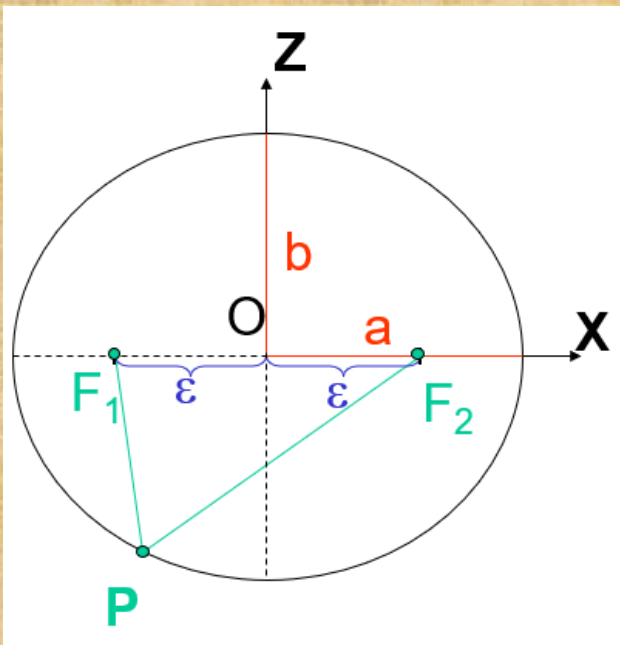
$f = (a-b)/a$ – flattening

used to establish a

datum: reference point

for large scale mapping

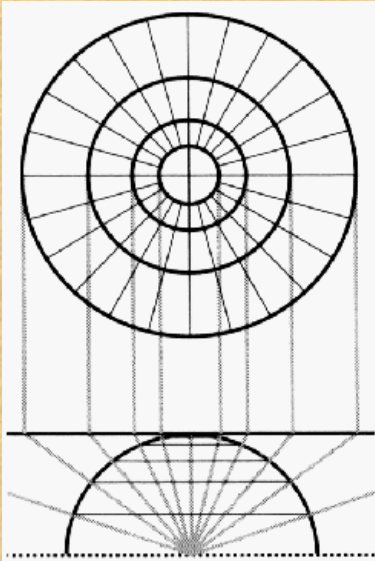
- Earth **datums** define standard values of the ellipsoid and geoid



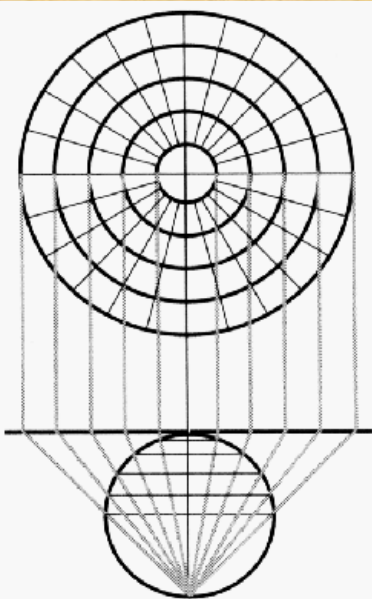
Map Projections

- Curved surface of the earth needs to be “flattened” to be presented on a map
- projection is the method by which the curved surface is converted into a flat representation
- defined as a mathematical function to convert between the surface location on the earth and the projected location on the map
- conversion from a geographic (spherical) reference system to a planar (Cartesian) system; e.g., lat/long \rightarrow x/y

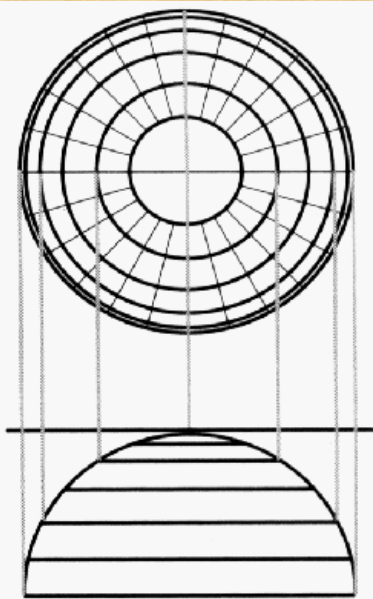
Azimuthal Projections



Gnomonic

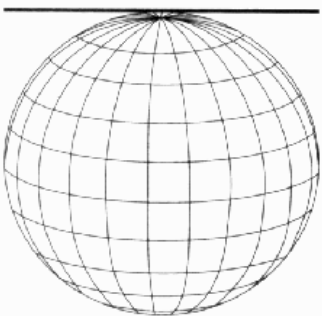


Stereographic



Orthographic

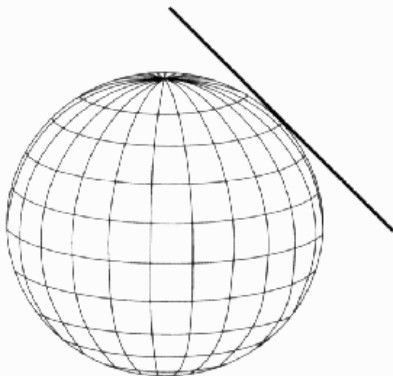
Azimuthal Projections Aspect



Polar

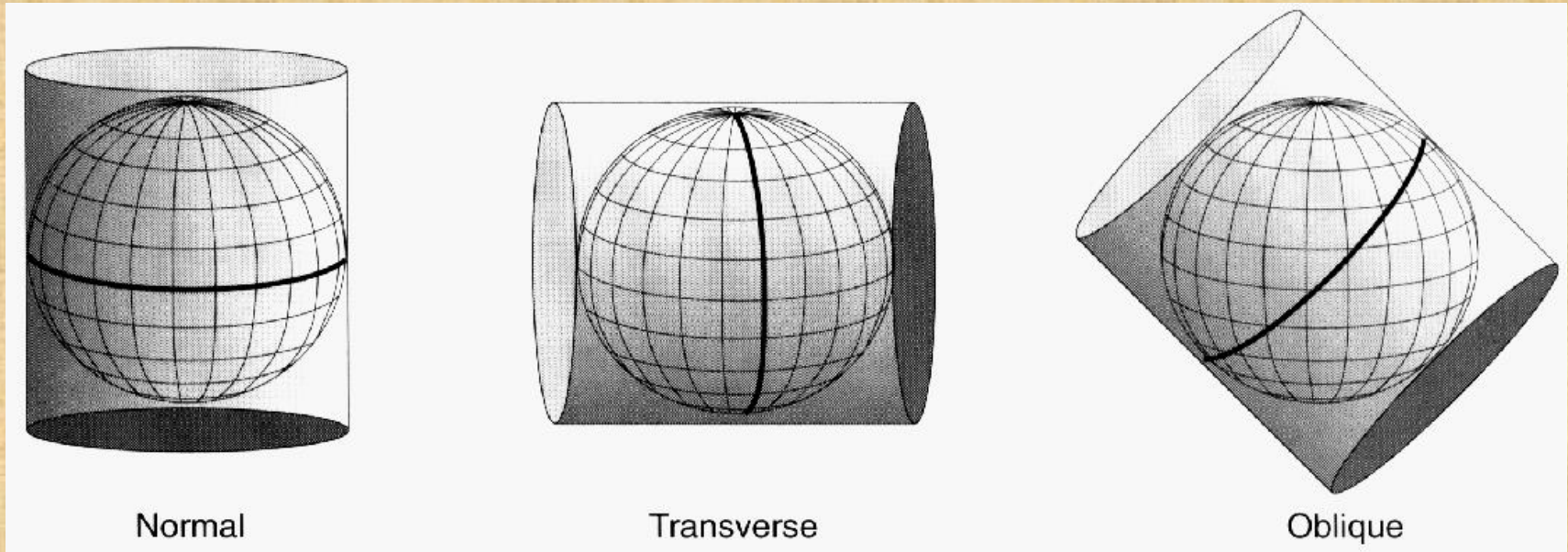


Equatorial

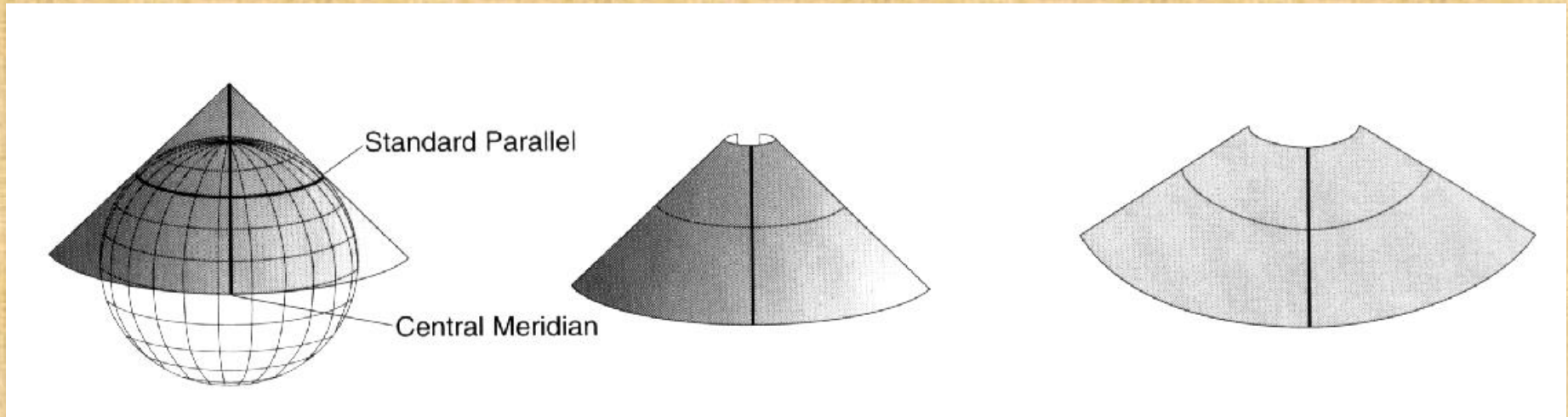


Oblique

Cylindrical Projections



Conic Projections

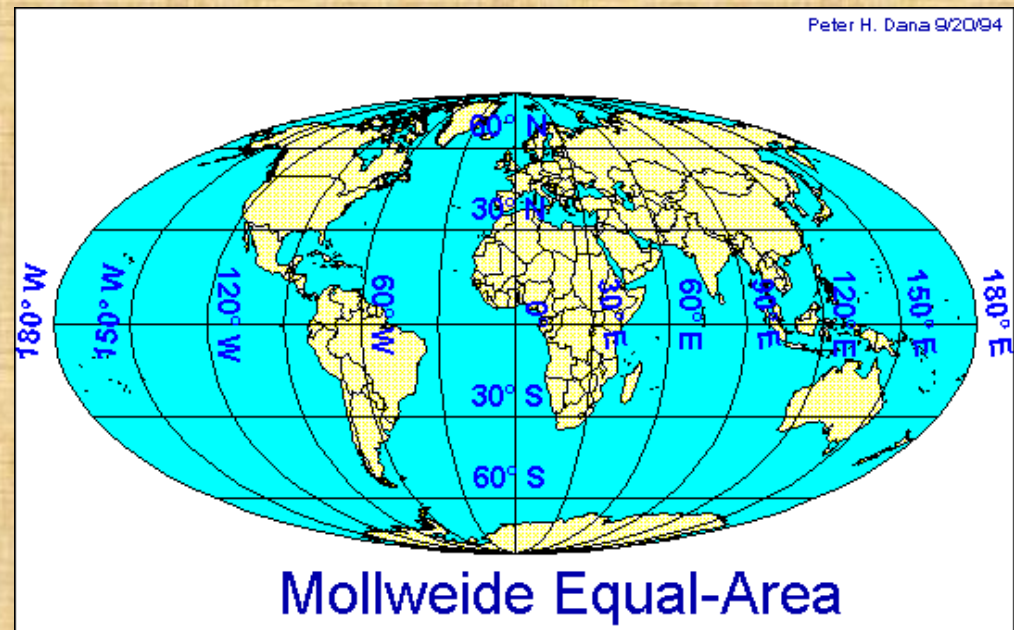


Distortion in Map Projections

- some distortion is inevitable
- less distortion, if maps show only small areas, but large if the entire earth is shown
- projections are classified according to which properties they preserve: area, shape, angles, distance

Equal area projections

- area on the map is proportional to the true area on the earth's surface
- required when area measures are made
- popular in GIS



Conformal projections

- preserve the shape of small features
- show angles (bearings) correctly
- useful in navigation

Equidistant projections

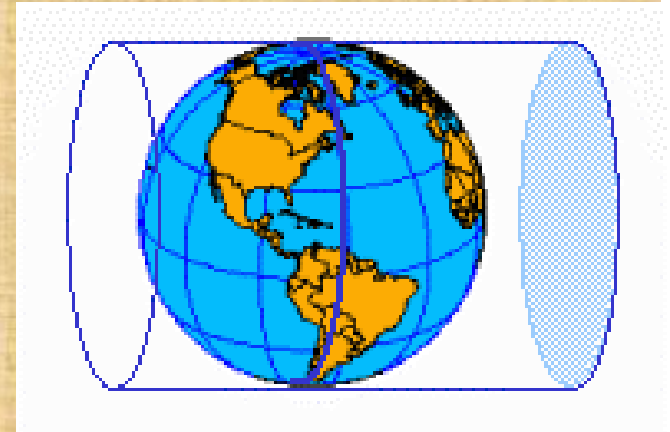
- represent the distances to other locations from either one or two points correctly

Compromise projections

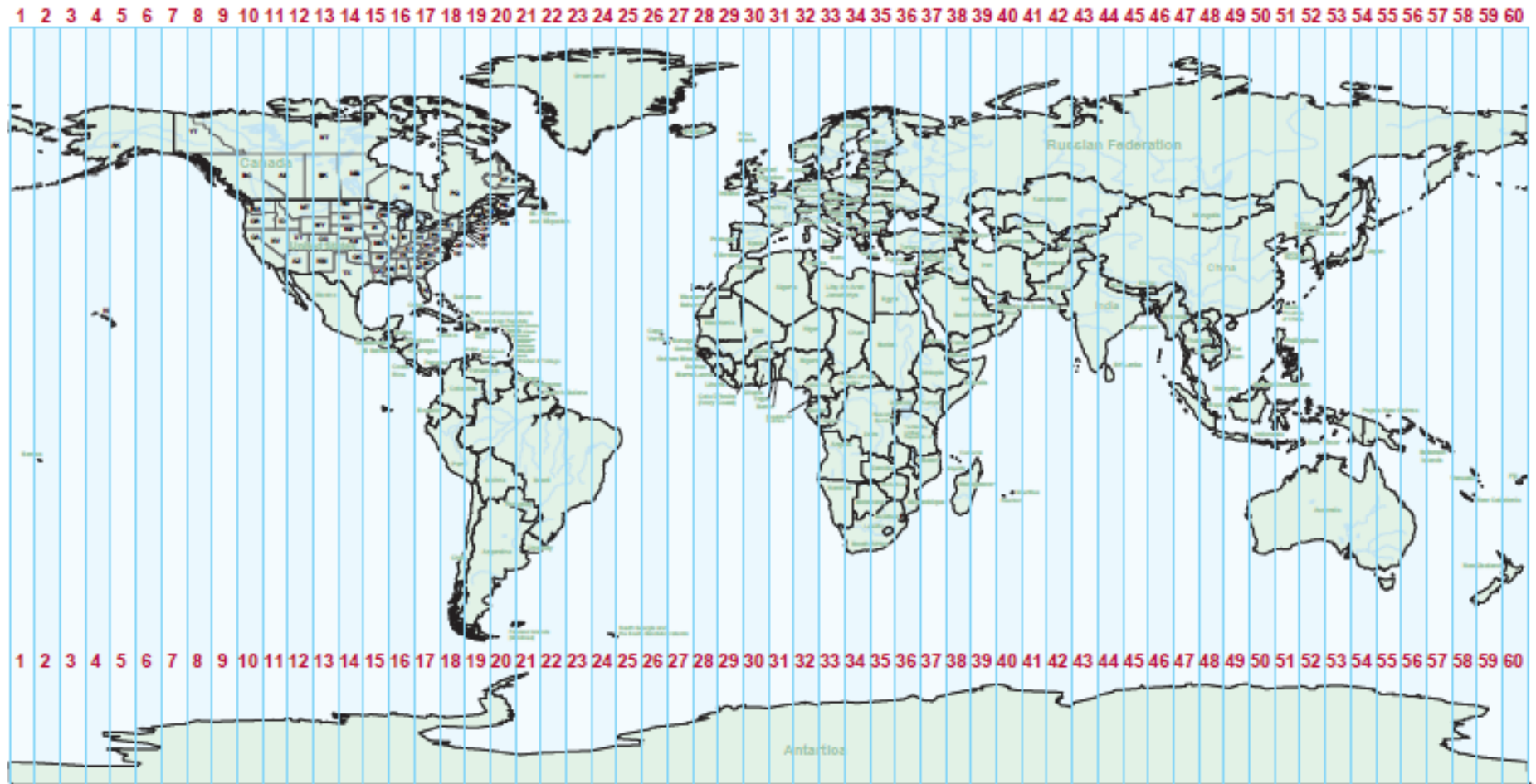
- do not preserve any property, but represent a good compromise between the different objectives
e.g., Robinson's projection for the world

UTM

- Universal Transverse Mercator (UTM)
- cylindrical projection with a central meridian that is specific to a standard UTM zone
- 60 zones cover the earth from East to West
- coordinates are usually measured in meters from the central meridian (x) and the equator (y)
- minimal distortions of area, angles distance and shape at large and medium scales
- very popular for medium scale mapping

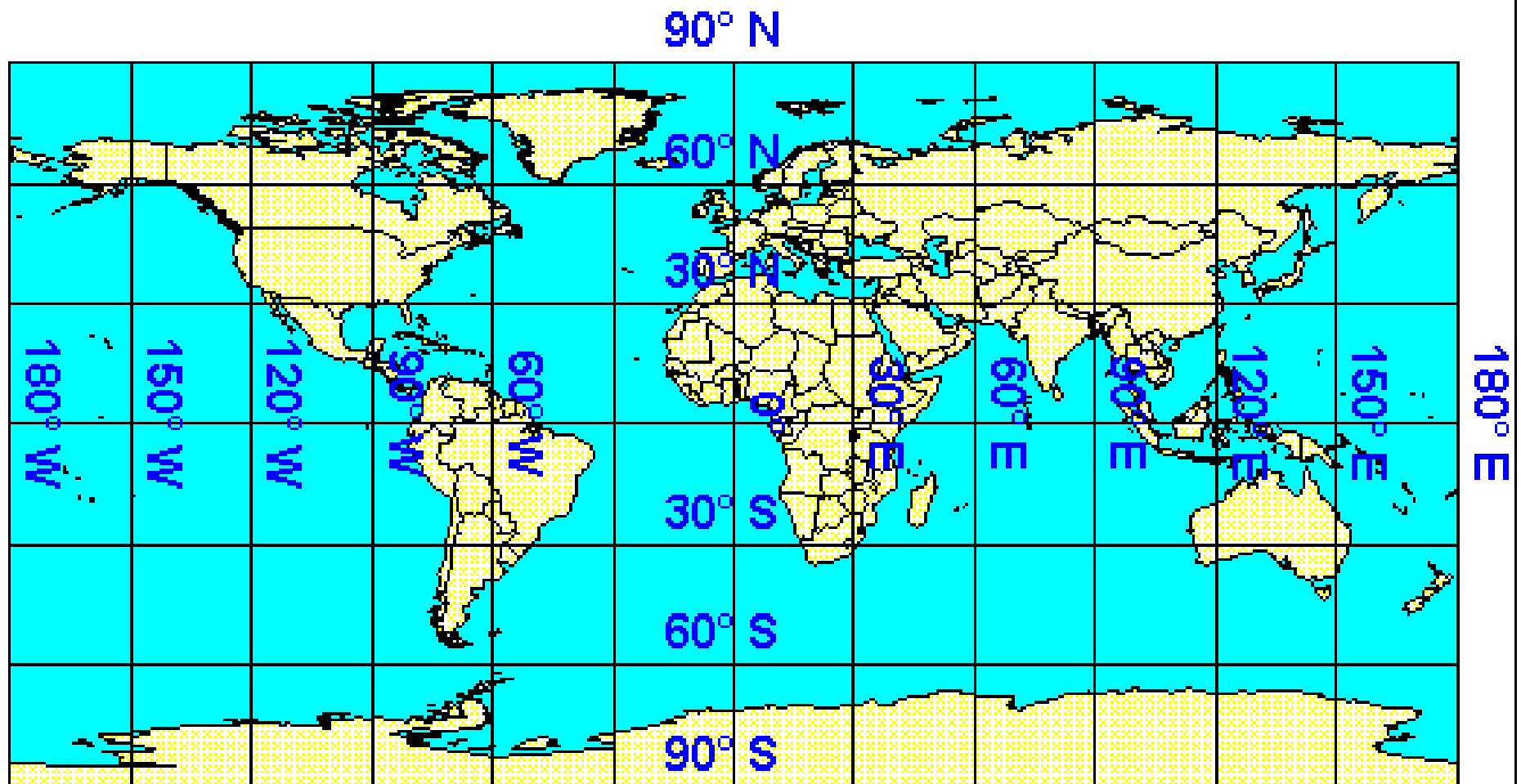


UTM Zone Map for the World



Lat/Long can also be represented in planar form (but is not technically a projection)

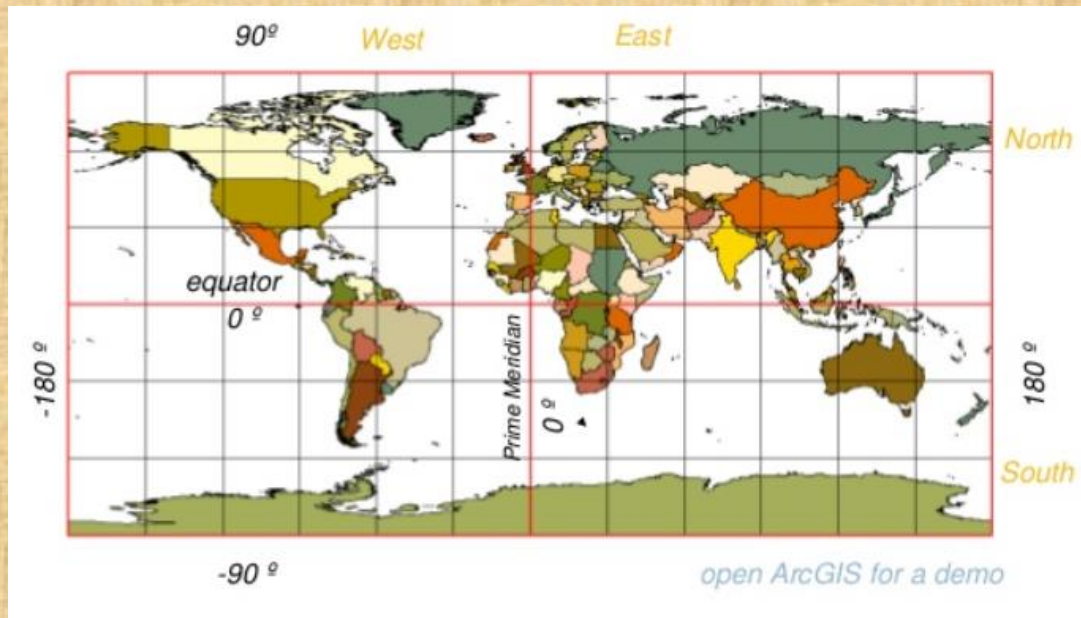
Peter H. Dana 9/20/94



Unprojected Latitude and Longitude

Parameters required for projecting a map

- latitude of origin
- central longitude (meridian)
- spheroid/datum
- false easting/northing (., an offset to avoid negative numbers)
- map units
- always record all information included on a map sheet

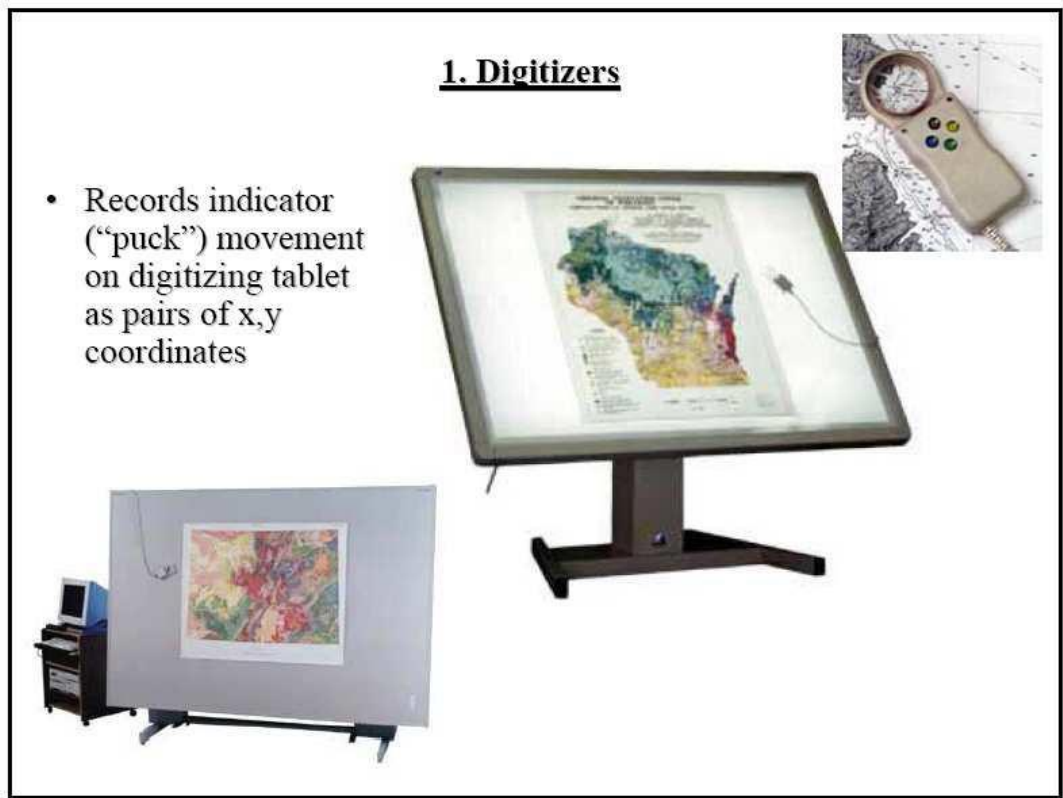


4. Digitization

Manual Vector Input

- O Digitizing Table
- O On Screen Digitizing
- O Text Files

Digitizing Table



- Sends an electrical impulse from the edges that is read by the puck to determine Location. Accuracy of tablets ranges form .01”to.002”

Two Methods of Digitization

Point Mode

- One (X,Y) Location is captured for each click of the puck button
- More accurate
- Requires less skill

Stream Mode

- The digitizer will send locations while the puck button is held down.
- Requires more skill
- Can be faster
- Slow operators will capture many more points than necessary

On Screen Digitizing

- The original is scanned and Georeferenced
- Features are captured using the mouse
- Less fatigue than using a tablet

Manual Digitizing

- Manual digitizing can cause repetitive motion injuries.
- Work in a location that minimizes stress on wrists and shoulders
- Take breaks
- Use a splint to keep wrist bent
- Seek Medical opinions at the first signs of problems.

Automated Tools

Gridline

- Command line ArcInfo command
- Need a near perfect image
- Can have a large amount of cleanup after conversion

ArcScan Extension

- New extension of ArcGIS
- Has clean up tools
- First tools for ArcGIS that work well

Text Files

- If you have a text file or table with X,Y values you can directly import them into
- ArcGIS.
- GPS Data

Secondary Data

- Large amount of data is now available
- Always check for existing data before creating it
- **Several groups of data exist**

Free data from the government

Government data available for a fee (USGS

Census, NOAA)

Internet map servers

Commercial data

Data from other GIS users

5. Basic Analysis in GIS

Database Recoding and Analysis

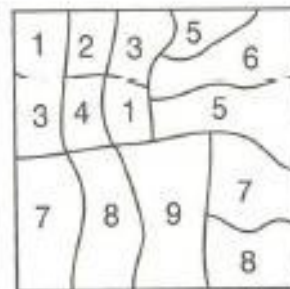
- A theme with many features and classes of data may have a good database, but its order (or organization) may not be apparent.
- By reducing the large number of classes into a manageable list (and rearranging into a logical sequence), you can gain a better understanding of the data, perceive new relationships, and obtain new information.
- Generalization of data is also known as data reduction.

Database Recode , Data Generalization

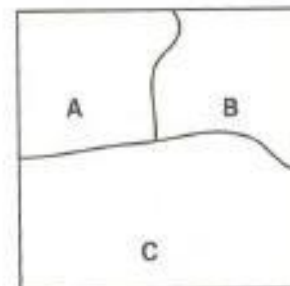
Image 1: Generalization of Soils

Soils Database

ATTRIBUTE CODE	SOIL TYPE	NEW SOIL RECODE
1	A1Z	A
2	A2Z	A
3	A3Z	A
4	A3Y	A
5	B1Y	B
6	B2Y	B
7	C6H	C
8	C6J	C
9	C7J	C

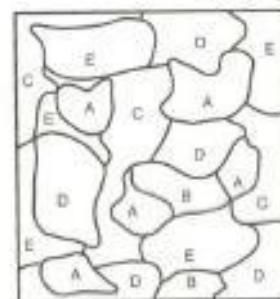


Map 1: Original Soil Map



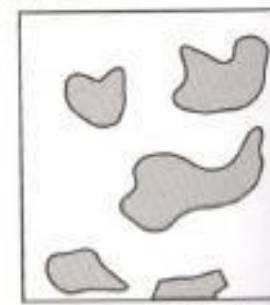
Map 2: Recoded Soils

Image 2: Recode for Agriculture



Map 3: Soils

RECODE:
A - B = AGRICULTURAL
C - E = NON-AGRICULTURAL



Map 4: Agricultural Soils

Overlay

- Visual Overlay
- Data Merging Overlay
- Overlay Principles
- Intersect and Union
- Overlay Options
- Clip Operations
- Mask and Replace
- Database Merging
- Append Themes

Visual Overlay

- The concept of GIS overlay is fairly simple: **combining two or more theme files**, usually in preparation for further analysis.
- Visual overlay is by **turning themes on and off** at the display.
- Visual overlays are advantageous in many ways, but they are not permanent (unless made into map). Analysis is largely by eye and therefore limited in capabilities.
- Making derived data depends on true merging of data.

Overlay

Image 1: Visual Overlay

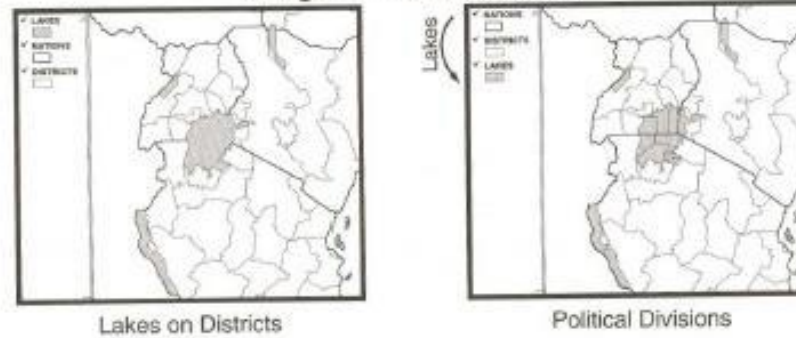


Image 2: Data Overlay

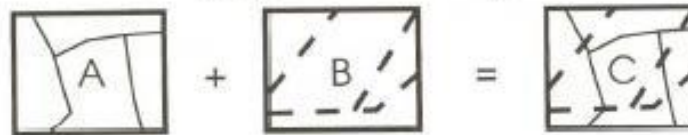
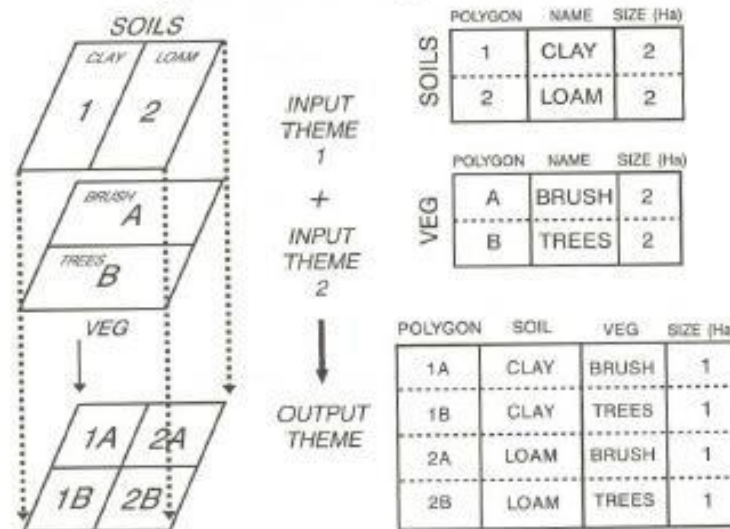


Image 3: Soil and Vegetation Overlay



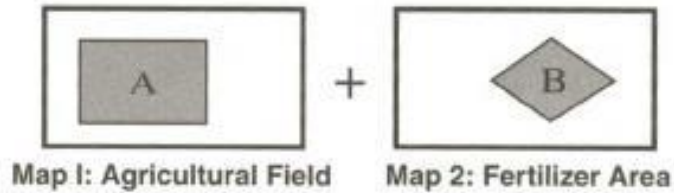
Data Merging Overlay

- There are many needs in GIS for combining several themes into a single one for permanent use.
- By merging the data rather than just visually overlaying, new themes with derived data are constructed.

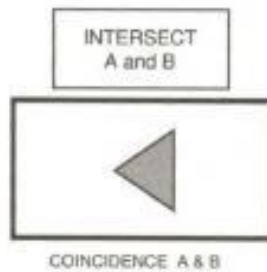
Overlay Principles

- There are various spatial relationship overlays that can be performed.
- The basic overlay relationships sometimes termed **Boolean overlays** because of the logic used.

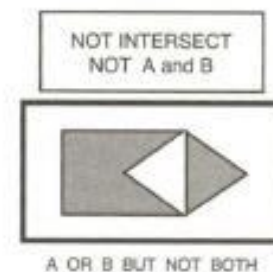
Boolean Overlays



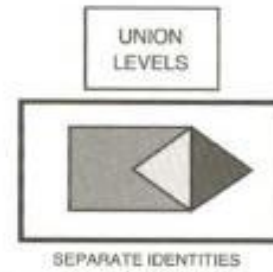
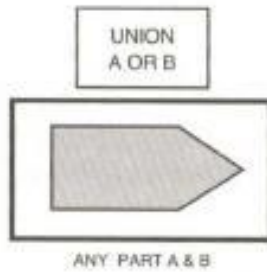
Intersect A and B



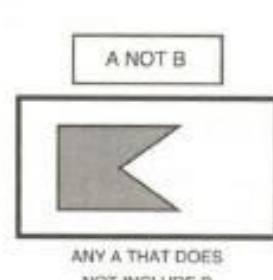
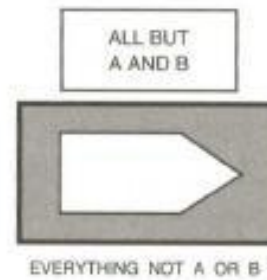
NOT Intersect A and B



Union A or B



Union levels

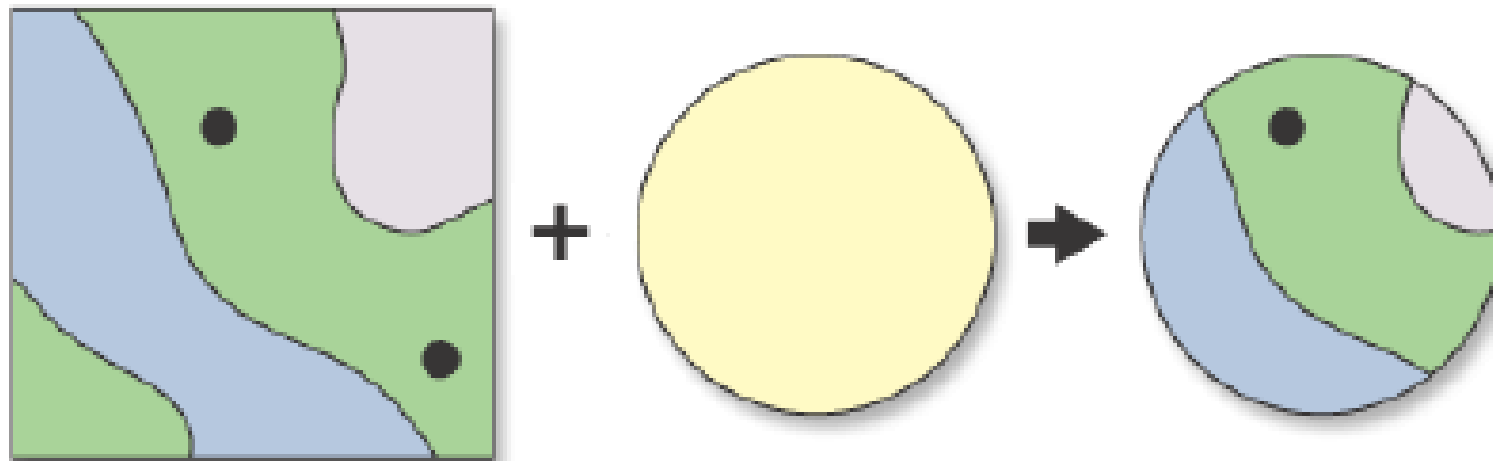


Intersect and Union

- Two of the most useful overlays are the intersect and union operations.
- Intersect merges only the parts that share common space (where the two themes overlap).
- Union combines all of the features involved.
- Union provides the comprehensive data merging rather than just visual display overlay.

Clip Operations

- Clip is an option that removes a selected part of one theme using another theme, selected features, or a graphic.
- In effect, it is an overlay operation that uses one part of a theme to select part of another by extraction (cutting and removal).



INPUT

CLIP FEATURE

OUTPUT

Clip operations...

Clip Options

Image 1: Points



Map 1: East Africa
Tsetse Fly Infestations



Map 2: Kenya Central Districts
Tsetse Points Clip Polygon

Image 2: Lines



Map 3: Regional
Hydrology



Map 4: Sudan and
Clipped Nile River

Image 3: Polygons



Map 5: 500-Km Insect Range



Map 6:
500-Km Districts

Exclude



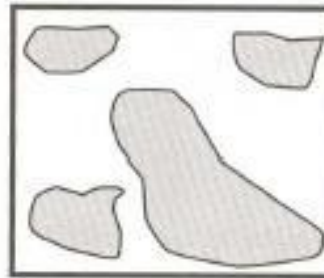
Map 7: 500-Km Exclude Zone

Mask and Replace

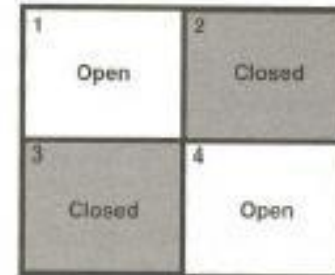
- **Mask** is a type of clip operation in which a designated section or set of features from one theme is used a “window” for selecting parts of a second theme.
- **Replace** (also called cover in some GISs) is another type of clip in some ways, in that it transfers selected features from one theme to another, covering those in the second theme.
- **Replace** is ideal for updating features spatially without having to go through elaborate recoding and overlay operations.
- **Replace** is essentially a convenient selected-feature overlay option.

Mask and Replace

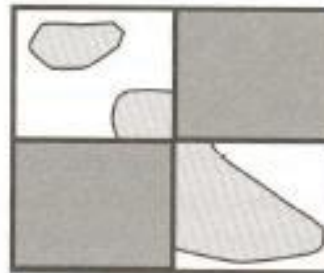
Mask



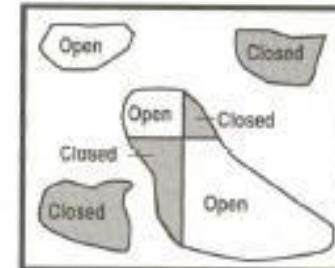
Map 1: Forests



Map 2: Mask Available Areas



Map 3: Timber Permit Areas



Map 4: Management Areas

Replace



Map 5: Vegetation: 1980
(Kudzu = dark tones)



Map 6: Kudzu: 1990

Replace



Map 7: Vegetation: 1990

Mask and Replace ...

Append Themes

- GIS permits joining adjacent or partially overlapping themes. This is called append, or sometimes merge or mosaic.
- In effect, the append operation adds one or more themes or maps to an existing one.
- Two requirements normally are that both be properly georeferenced and that they share at least one common item in the database in order to have a join item.
- Append is simply a matter of joining features according to their actual world locations.

Append...

Append

Northwest



Southwest



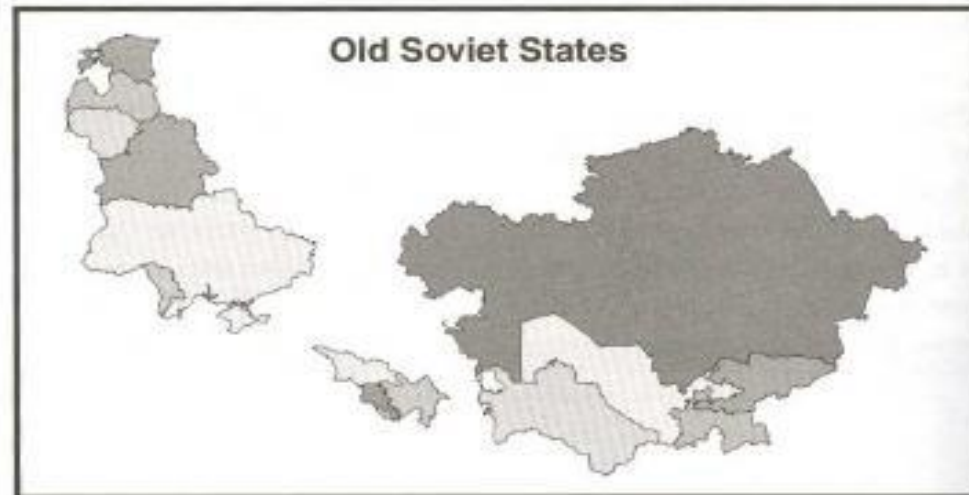
West



East



Old Soviet States



Map Algebra: Raster Cell Overlay

- The use of mathematical operation is called map algebra, which usually includes Add, Subtract, Multiply, Divide, Exponentiate, and other operators.

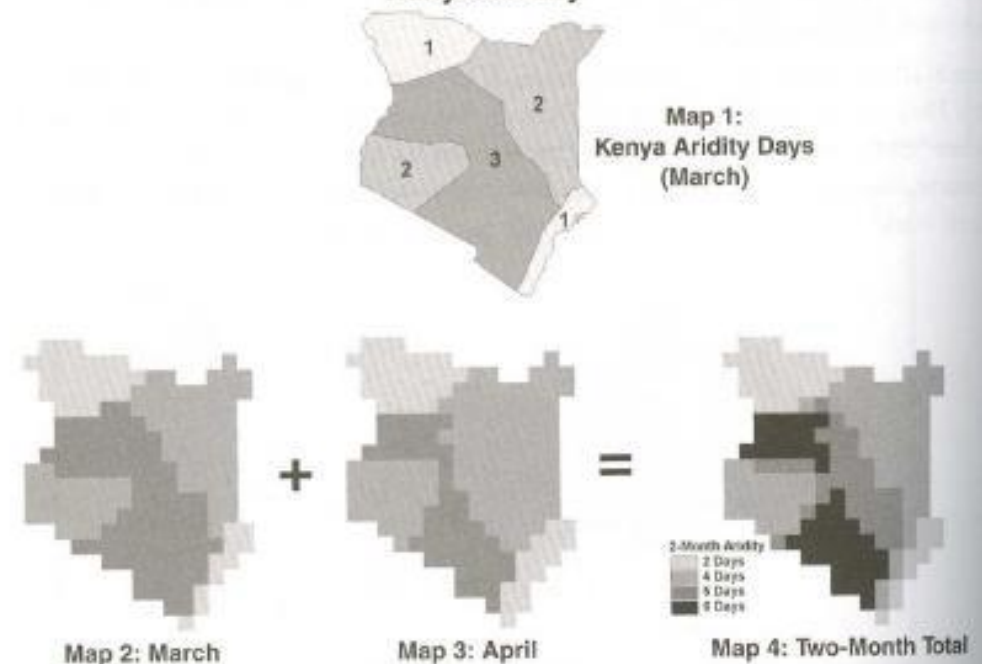
Map Algebra Raster Cell Overlay

Image 1: Overlay Using Add

Input Theme A			Input Theme B			Output Theme C				
1-1 3	1-2 3	1-3 4	+	1-1 4	1-2 2	1-3 2	=	7	5	6
2-1 0	2-2 1	2-3 0		2-1 5	2-2 5	2-3 5		5	6	5
3-1 2	3-2 4	3-3 6		3-1 4	3-2 1	3-3 1		6	5	7

Raster Cell 1-1: $3 + 4 = 7$
Raster Cell 1-2: $3 + 2 = 5$
Raster Cell 1-3: $4 + 2 = 6$

Image 2: Map Algebra Application
Kenya Aridity



Map Algebra:

Multiplication and

Maximum

The multiplication and maximum functions are two other common types of overlay operations that make use of map algebra.

Map Algebra Multiply and Maximum

Image 1: Overlay Using Multiply



Image 2: Overlay Using Maximum

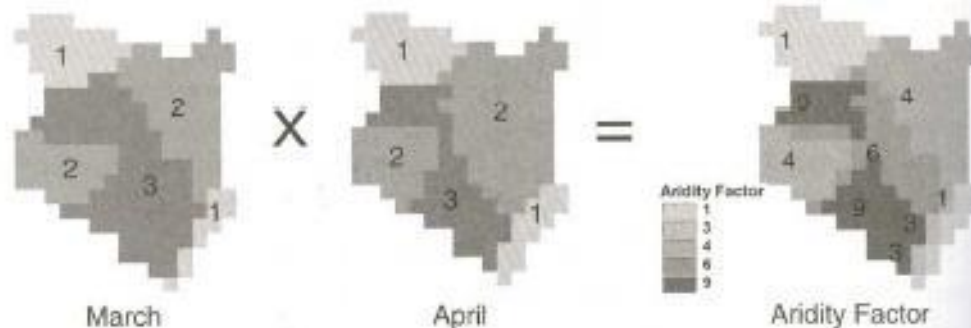
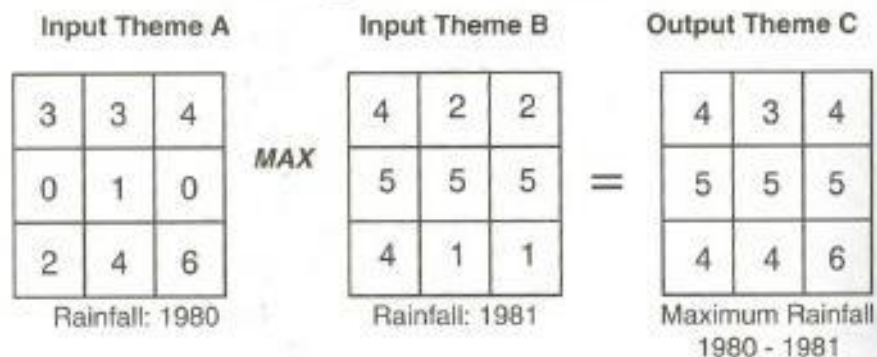


Image 3: Rainfall Cells



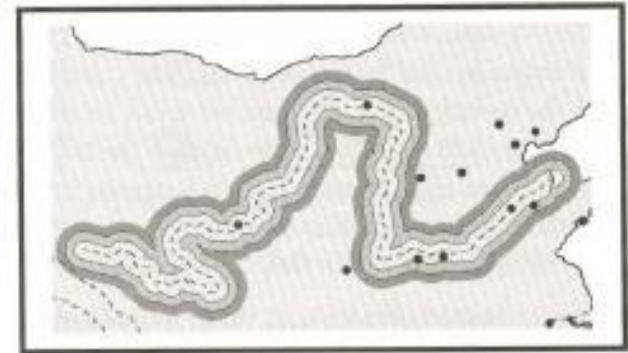
Buffers

- Building zone around features is a standard and very useful GIS capability (but difficult to do manually).
- Buffer is the common term for the zones, though other names are associated with this process, such as **spread**, **search**, and **corridor**.
- Buffers have many uses, mostly dealing with distance from selected features.

Buffers



Map 1: 100-Km Buffers
Point, Line, Polygon

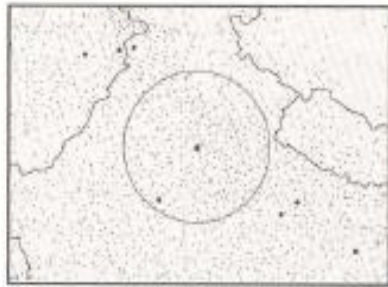


Map 2: Multiple 50-Km Buffers



Map 3: Pseudo-Buffer Selection
Yangtze Cities, 150-Km

Buffer Applications



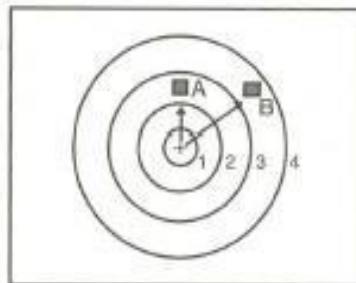
Map 1: New Delhi Region
300-Km Buffer



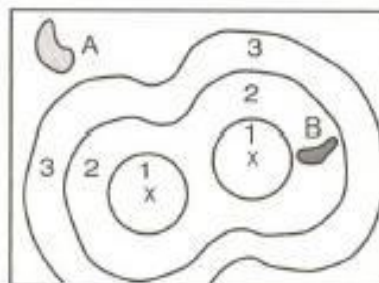
Map 2: 300-Km Urban Selection



Map 3: Niger River Flood Zone
Endangered Towns and Villages



Map 4: Postal Zones
Cost of Mailing



Map 5: Pollution Zones
Decreasing Impact

- WETLAND
- X POLLUTION SOURCE
- 1- 2- 3-KM ZONES

Niger River Information System



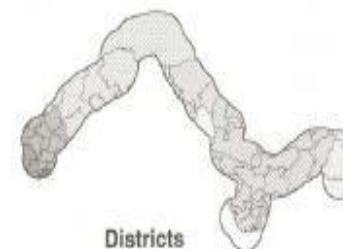
Niger River Region
150-Km Buffer



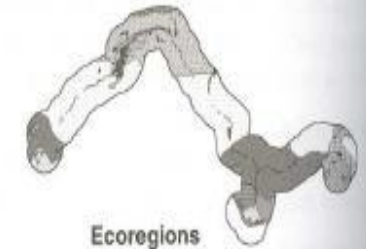
Nations



Cities and Villages



Districts



Ecoregions

Statistical Reporting and Graphing

- Graphs and statistical reports are useful.

- They provide summary information, new information, and possible insights to aspects that graphics do not provide.

- GIS reports can be simple text and graphics, or they can include documents with maps, many types of graphs and plots, various tables, pictures, and other visualization tools.

Reports and Graphs

Image 1: Report and Graph

Agricultural Report

District	Ave Field Size	Min Yield	Max Yield	Min Distance
A	128	55	123	54
B	220	65	111	34
C	145	52	98	45
D	200	50	113	66

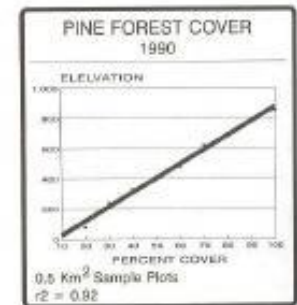
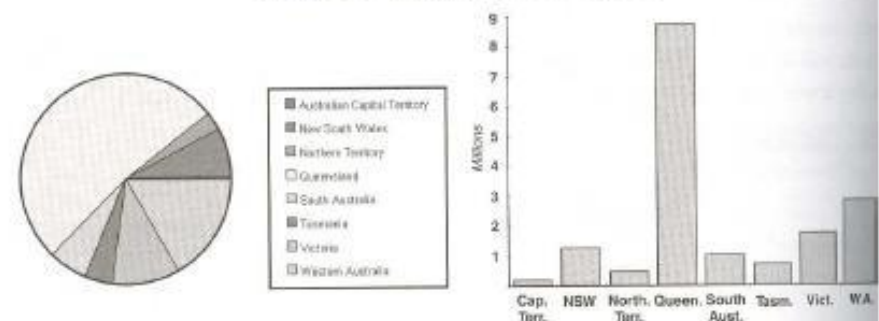


Image 2: Arizona Demographics



Image 3: Australia Population

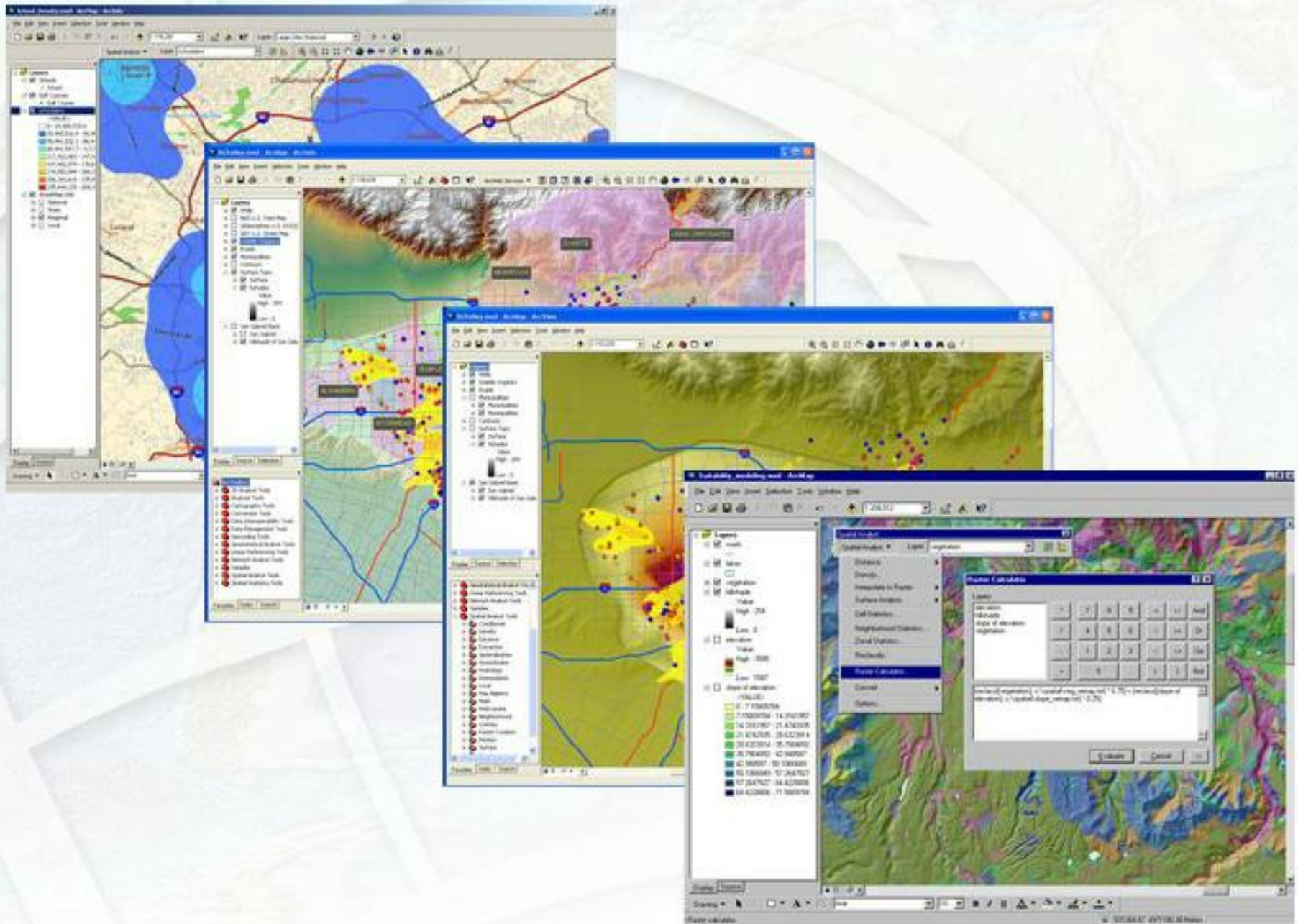


6. Spatial Analysis Using ArcGIS

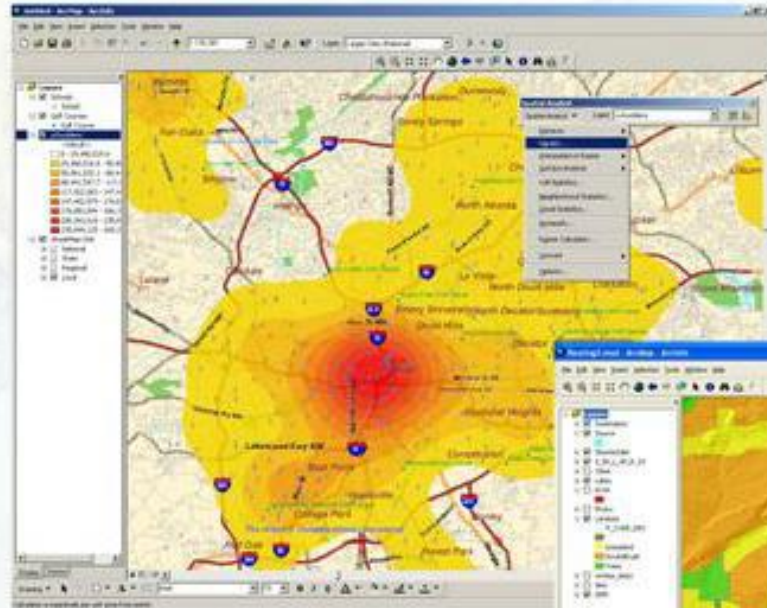
ArcGIS Spatial Analyst Tool

- **ArcGIS Spatial Analyst** provides a range of spatial modeling and analysis tools.
- Using ArcGIS Spatial Analyst, you can
 - Create, query, map, and analyze cell-based raster data.
 - Perform integrated raster/vector analysis.
 - Derive new information from existing data.
 - Query information across multiple data layers.
 - Fully integrate cell-based raster data with traditional vector data sources.

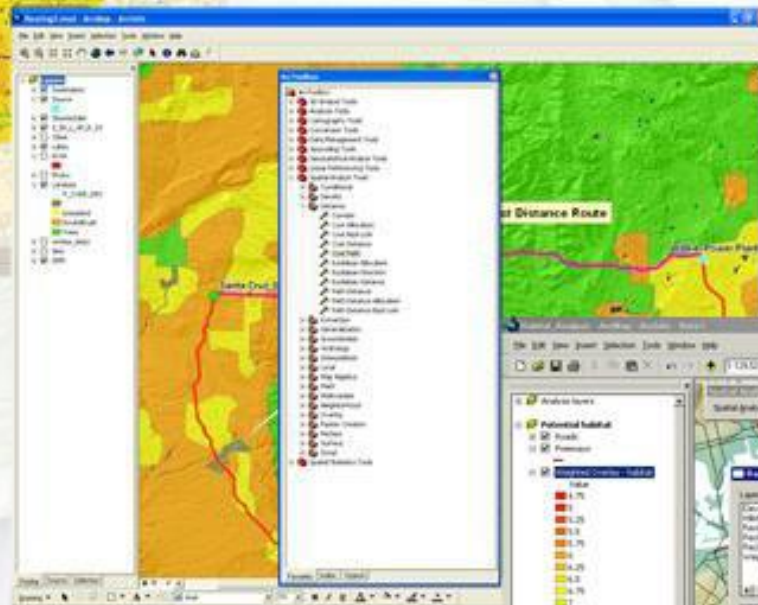
Performs complex spatial Analysis



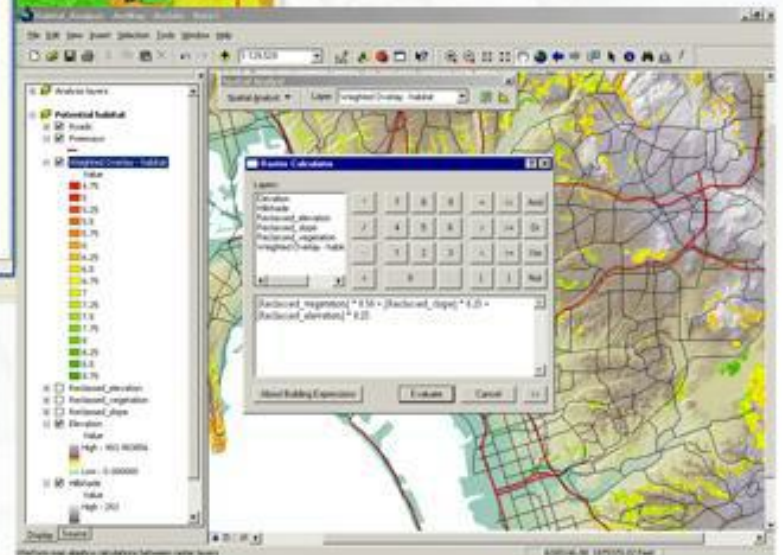
Performs complex spatial Analysis



Density Mapping



Distance Analysis



Weighted Overlay

Functions Associated with Spatial Analysis

- **Local Functions** work on single cells
- **Focal Functions** work on cells within a neighborhood
- **Zonal Functions** work on cells within zones
- **Global Functions** work on all cells
- **Application Functions** to solve specific applications.
- **Density Function** distributes a measured quantity of an input point layer throughout a landscape to produce a continuous surface.

Spatial Analysis Functions...

- **Surface Generation Functions**

(or surface interpolators) create a continuous surface from a sampled point values.

- Inverse Distance Weighted

(IDW)

- Polynomial Trend Surface

- Spline

- Kriging

- **Surface analysis functions:**

- Slope,

- Aspect,

- Hillshade,

- Viewshed,

- Curvature,

- Contour

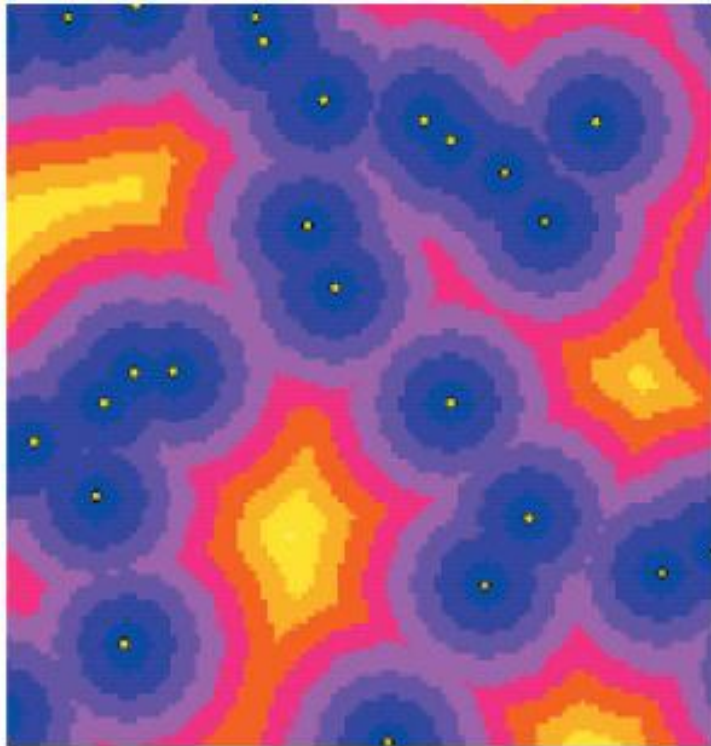
Spatial Analysis Functions...

- **Hydrologic analysis functions** provide methods for describing the hydrologic characteristics:
 - Flow direction, flow accumulation, stream networks, Watershed boundary)
 - Reclassification
 - Raster Calculator (map algebra)
 - Conversion of vector and raster

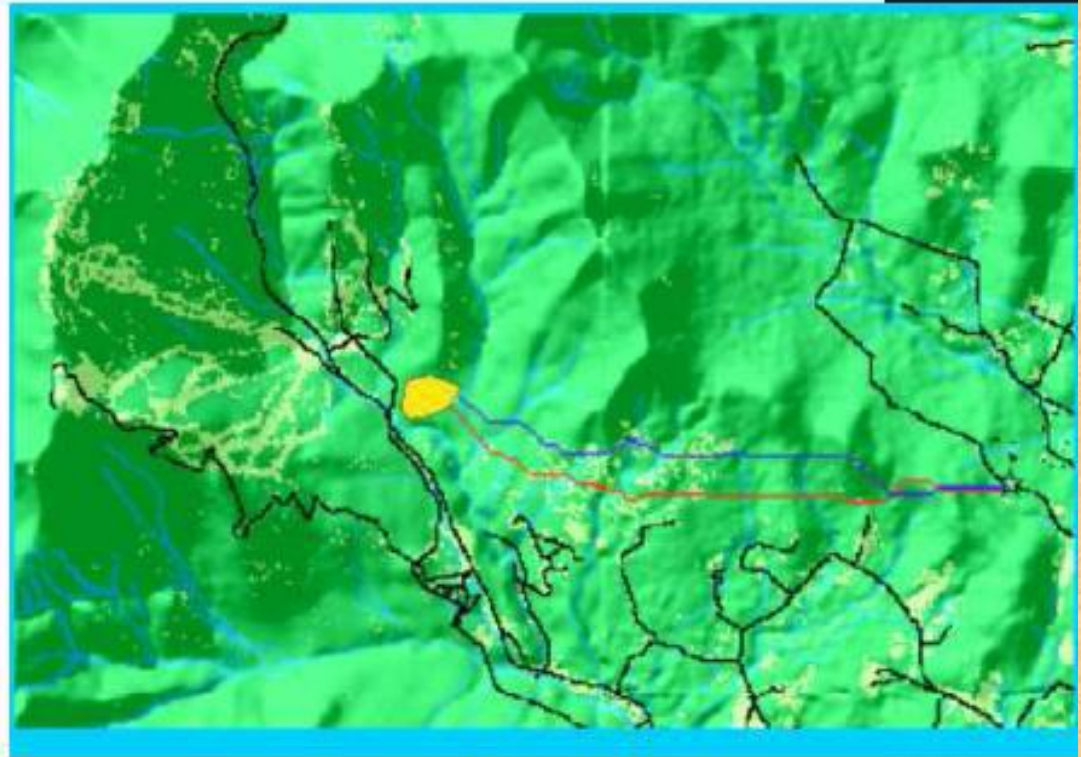
Mapping Distance

- The *Straight Line Distance function* measures the straight line distance from each cell to the closest source.
- The *Cost Weighted Distance function* modifies the *Straight Line Distance* by some other factor, which is a cost to travel through any given cell. For example, it may be shorter to climb over the mountain to the destination, but it is faster to walk around it. Cost can be money, time, or preference.
- The Distance and Direction raster datasets are normally created from *Cost Weighted Distance* function to serve as inputs to the path finding function, *the shortest (or least-cost) path*.

Mapping Distance



The straight line distance to the nearest town from every location.



Cost weighted distance

The purple line represents a cost distance where each input raster (landuse and slope) had the same influence. The mustard line represents a cost distance where the slope input raster had a weight (influence) of 66%.


Allocation Functions

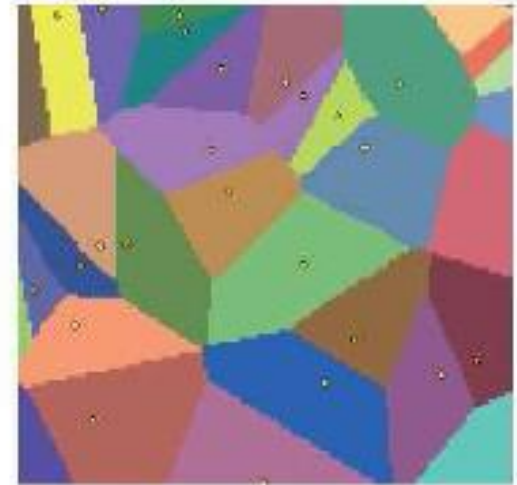
- Allows you to identify which cells belong to which source based on straight line distance function or cost weighted distance function.

	1	1			
		1			
2					



1	1	1	1	1	1
1	1	1	1	1	1
1	1	1	1	1	1
2	1	1	1	1	1
2	2	2	1	1	1
2	2	2	2	2	1

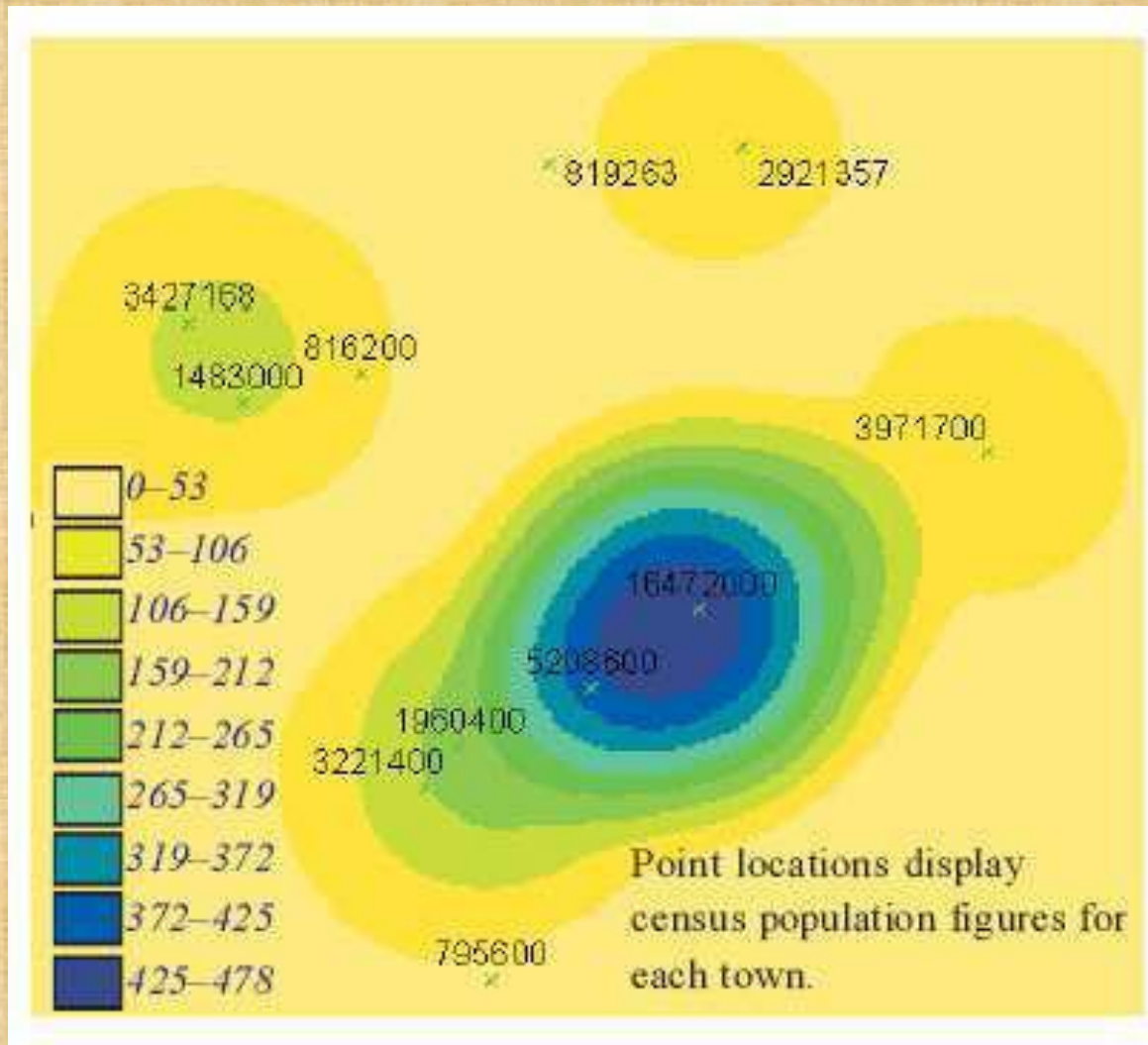
 = NoData



Allocating cells to sources: Which areas are served by which town?

Mapping Density

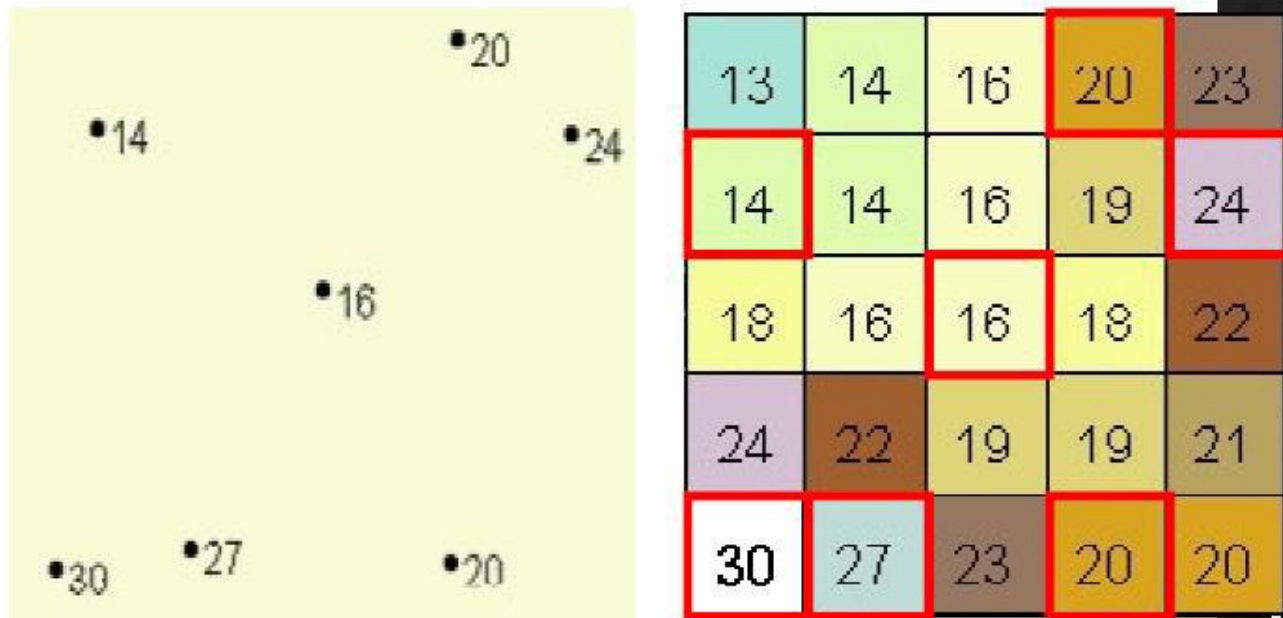
- Spread point values over a surface



Interpolating to Raster

- Interpolation to predict values for cells from a **limited number** of sample data points.
- Visiting every location is usually difficult or expensive.
- Assumption: spatially distributed objects are **spatially correlated**. In other words, things close together tend to have similar characteristics (spatial autocorrelation).

◉ Few sample points - to fill all cells



Interpolation Techniques

- **Deterministic and Geostatistical.**
- **Deterministic interpolation** techniques create surfaces from measured points based on either the *extent of similarity* (e.g., Inverse Distance Weighted) or the *degree of smoothing* (e.g., radial basis functions).
- **Geostatistical interpolation** techniques (e.g., kriging) utilize the *statistical properties* of the measured points.

Deterministic Interpolation Techniques

- **Global techniques** calculate predictions using the entire dataset: *Global polynomial*
- **Local techniques** calculate predictions from the measured points within neighborhoods, which are smaller spatial areas within the larger study area: *Inverse Distance Weighted, local polynomial and radial basis functions (Spline).*

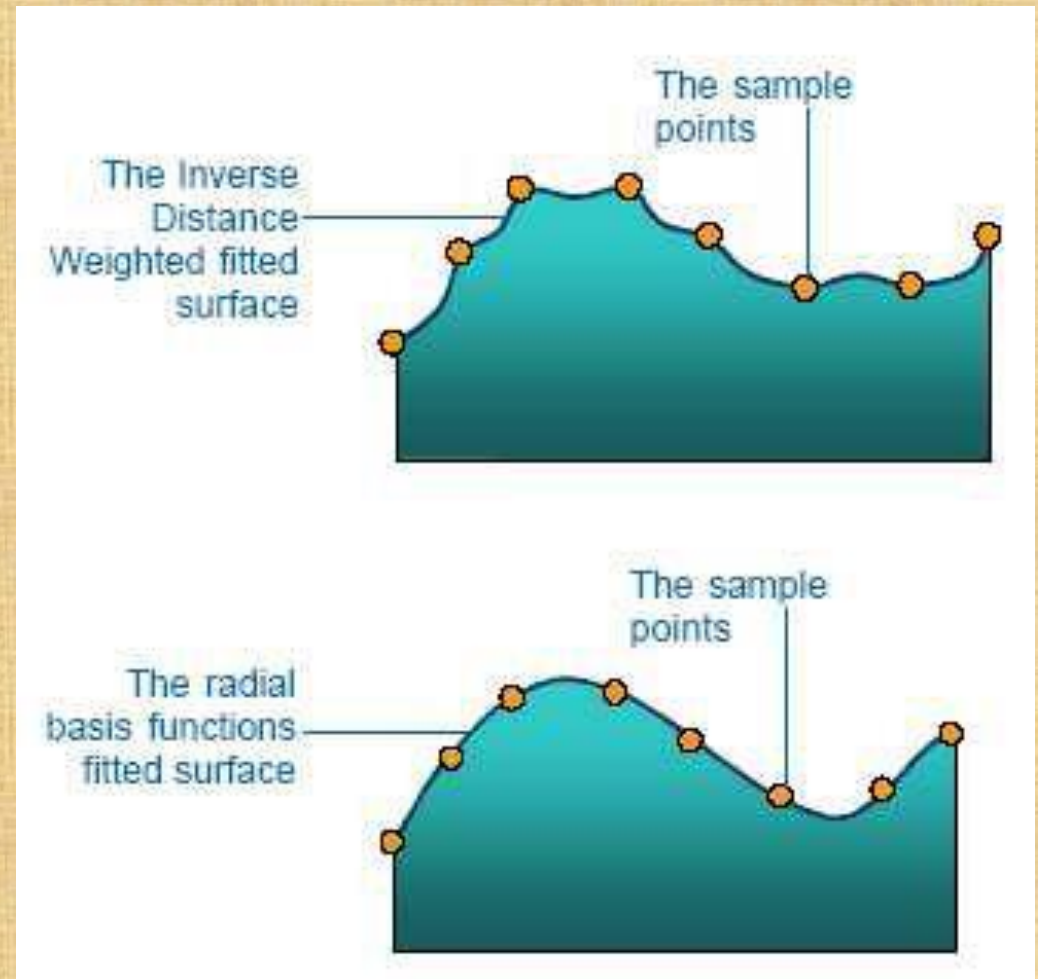
Inverse Distance Weighted (IDW)

- Each sample point has a local influence that diminishes with distance.
- Weights the points closer to the processing cell more heavily than those farther away.
- Operator controls how weighting is done.
 - Power** : High power gives more weight to closer points.
 - Radius type**: Considers how far away to look.
 - Barrier**: Search can be limited by other polygons.

Radial Basis Function (Spline)

Radial basis functions (RBF) methods are a series of exact interpolation techniques, that is, the surface must go through each measured sample value.

- There are five different basis functions: thin-plate spline, spline with tension, completely regularized spline, multiquadric function, and inverse multiquadric spline



IDW will never predict values above the maximum measured value or below the minimum measured value but Spline can

Radial Basis function

- When running spline in Spatial Analyst

Weight:

- *Regularized*: 0, 0.001, 0.01, 0.1, 0.5
- The higher the weight, the smoother the surface
- *Tension*: 0, 1, 5, 10
- The higher the value is, the coarser the surface

Number of points:

- The more points used in the calculation the smoother the surface.

Geostatistical interpolation

- Geostatistical techniques create surfaces incorporating the **statistical properties of the measured data**. These techniques produce not only prediction surfaces but also error or **uncertainty surfaces**, giving you an indication of **how good** the predictions are.

Kriging family:

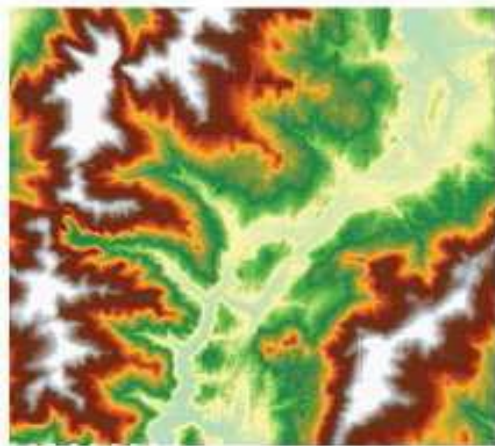
- Simple kriging assumes a known constant trend
- Ordinary kriging assumes an unknown constant trend.
- Universal kriging assumes a general linear trend model
- Co-kriging is kriging with more than one parameter

Kriging..

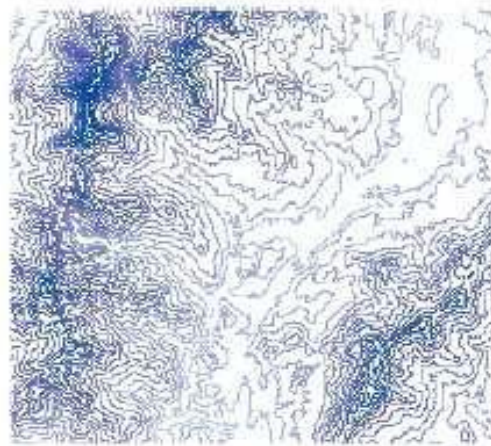
- Kriging is divided into two distinct tasks:
- Quantifying the structure, known as variography, is where you fit a spatial-dependence model to your data.
- To make a prediction for an unknown value for a specific location, kriging will use the fitted model from variography, the spatial data configuration, and the values of the measured sample points around the prediction location.

Performing Surface Analysis: Contours

- Contours are polylines that connect points of equal value, such as elevation, temperature, precipitation, pollution, or atmospheric pressure.



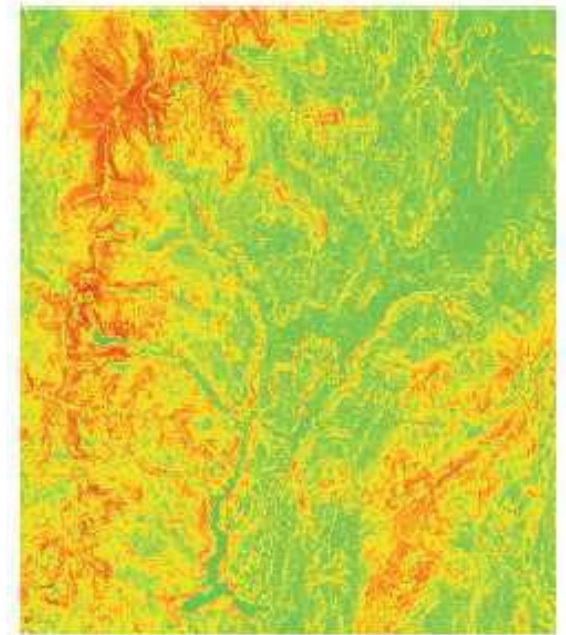
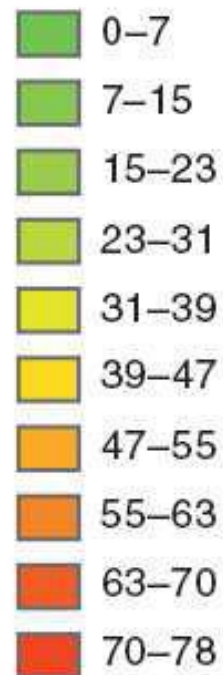
Input elevation dataset



Output contour dataset

Attributes of Contour			
FID	Shape	ID	CONTOUR
0	Polyline	1	1800
1	Polyline	2	1200
2	Polyline	3	1000
3	Polyline	4	2400
4	Polyline	5	1200
5	Polyline	6	3600
6	Polyline	7	1200
7	Polyline	8	1200
8	Polyline	9	1600
9	Polyline	10	3200

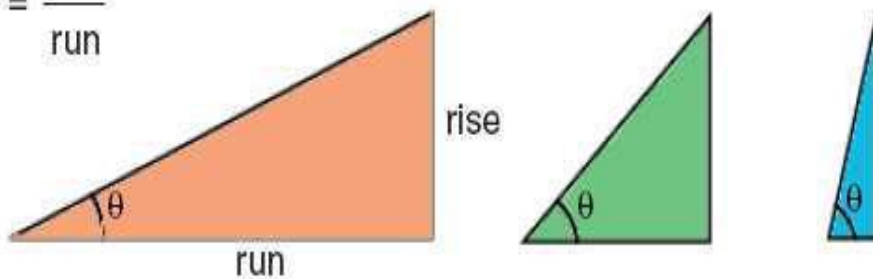
• SLOPE



Output slope dataset

Degree of slope = θ Percent of slope = $\frac{\text{rise}}{\text{run}} * 100$

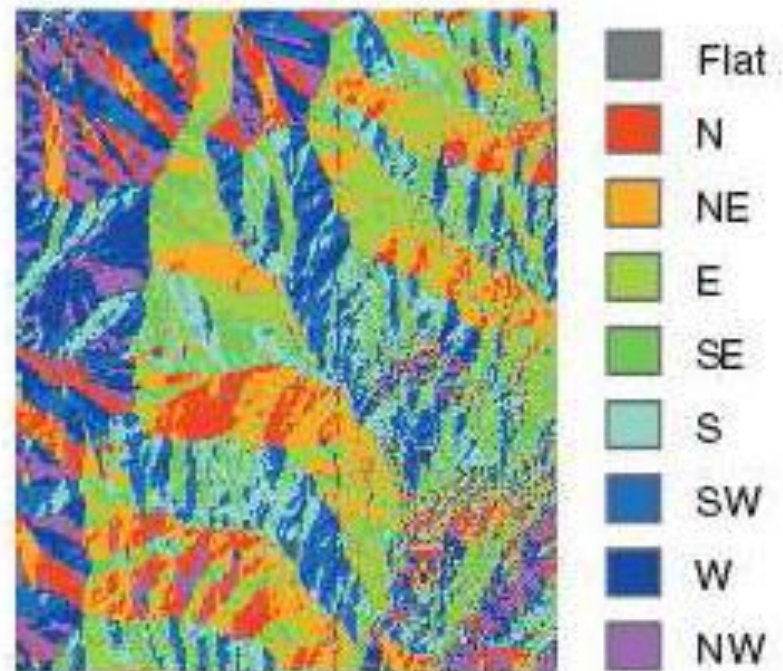
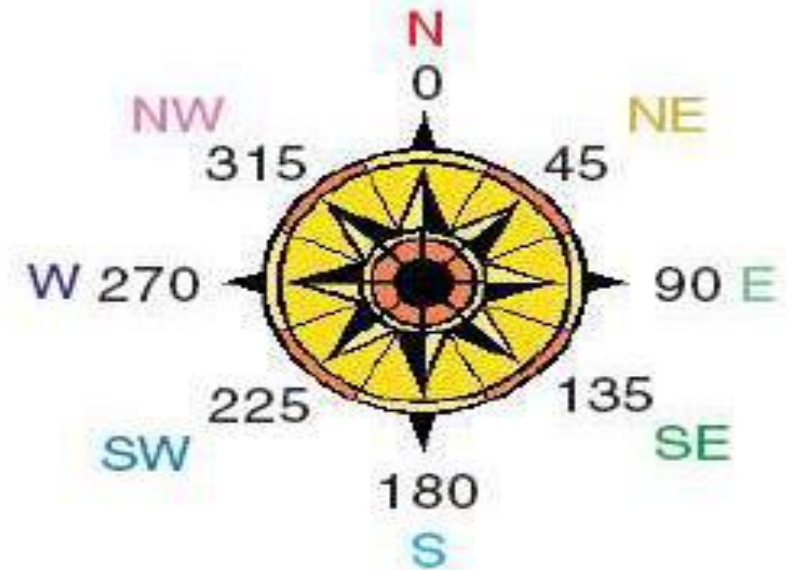
$\tan \theta = \frac{\text{rise}}{\text{run}}$



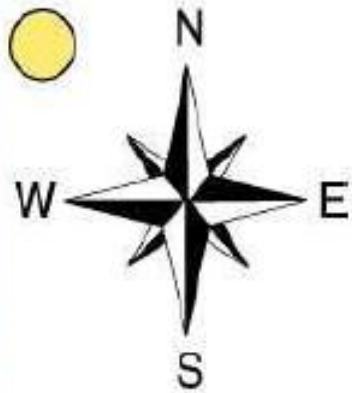
Degree of slope =	30	45	76
Percent of slope =	58	100	375

ASPECT

- The value of each cell in an aspect dataset indicates the direction the cells slope faces. Flat slopes have no direction and are given a value of -1.

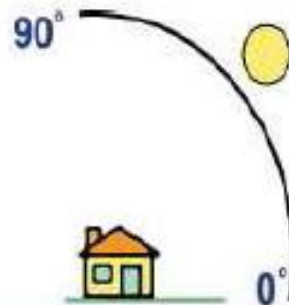


HILLSHED



Azimuth is the angular direction of the sun, measured from north in clockwise degrees from 0 to 360. An azimuth of 90 is east. The default is 315 NW.

Altitude is the slope or angle of the illumination source above the horizon. The units are in degrees, from 0—on the horizon—to 90 degrees—overhead. The default is 45 degrees.



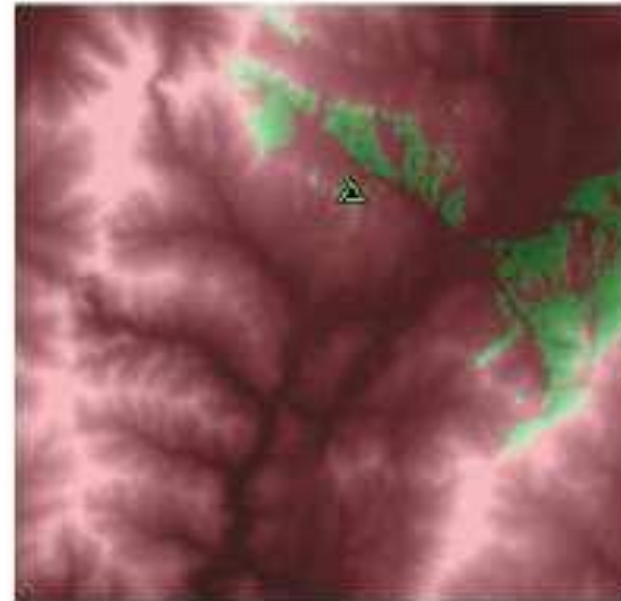
Setting a hypothetical light source and calculating the illumination values for each cell in relation to neighboring cells. It can greatly enhance the visualization of a surface for analysis or graphical display.

VIEWSHED

- Viewshed identifies the cells in an input raster that can be seen from one or more observation points or lines.
- It is useful for finding the visibility. For instance, finding a well exposed places for communication towers.



The elevation in the area of the observation point



Green cells are visible from the observation point, red cells are not visible.

CONVERSION



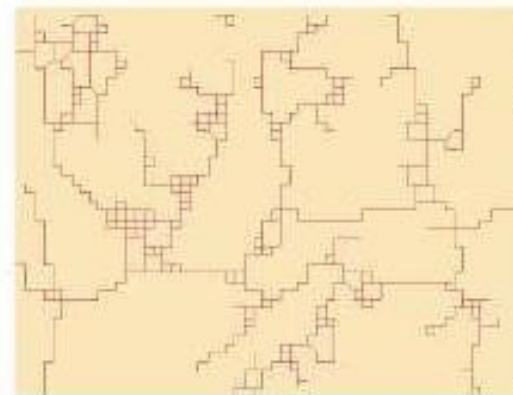
Input polylines



Output raster



Input raster



Output polylines

- Feature (polygon, polyline, points) to raster.

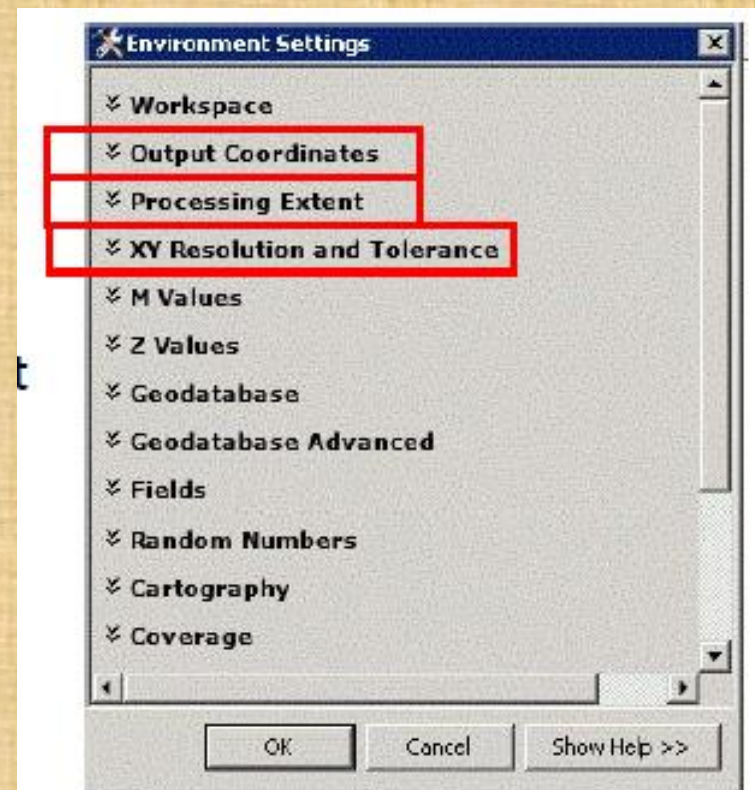
- Raster to feature (polygon, polyline, points)

7. Spatial Analyst: this extension can create, map, and analyze cell based raster data; perform integrated raster/vector analysis; derive new information from existing data

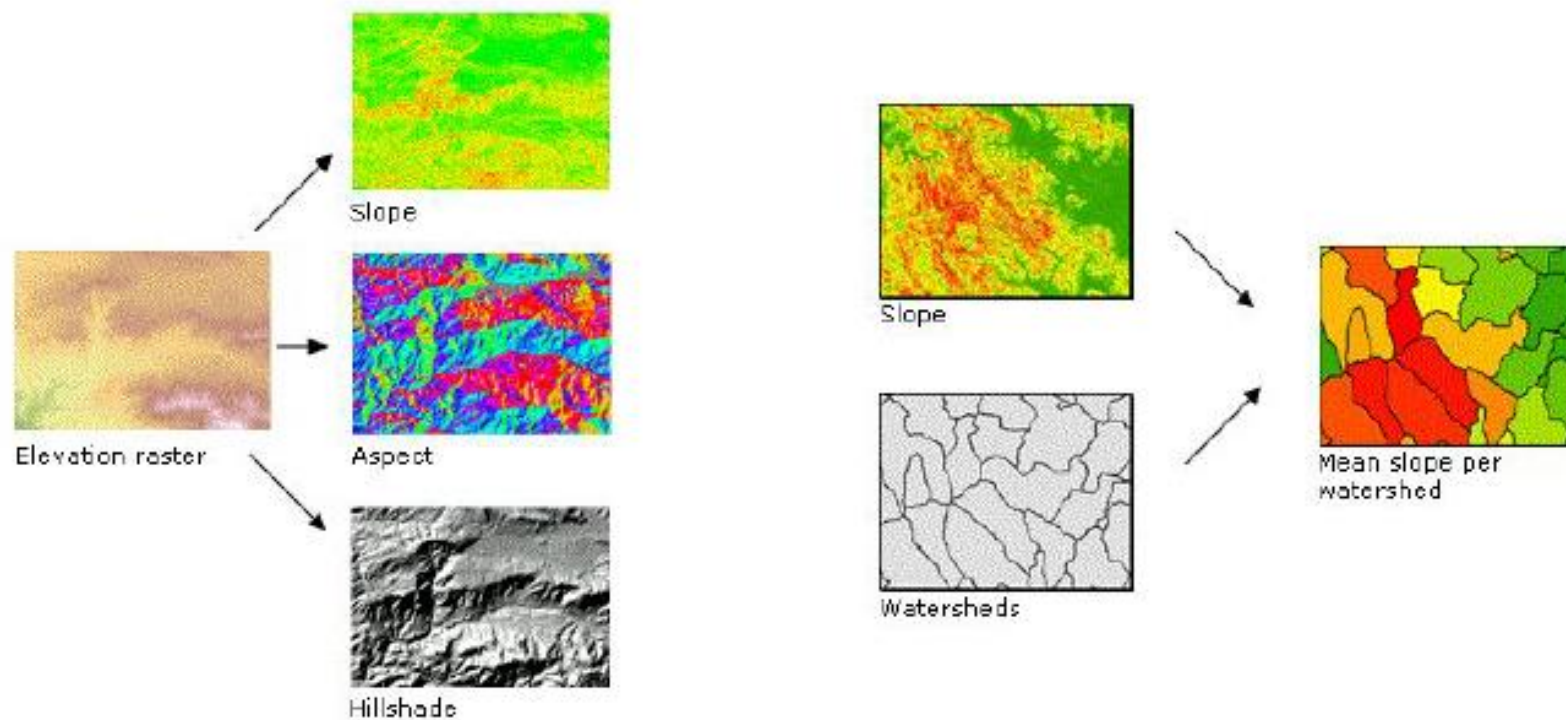
- Some properties have to be fixed before using any spatial analyst tools

Environments < Geoprocessing

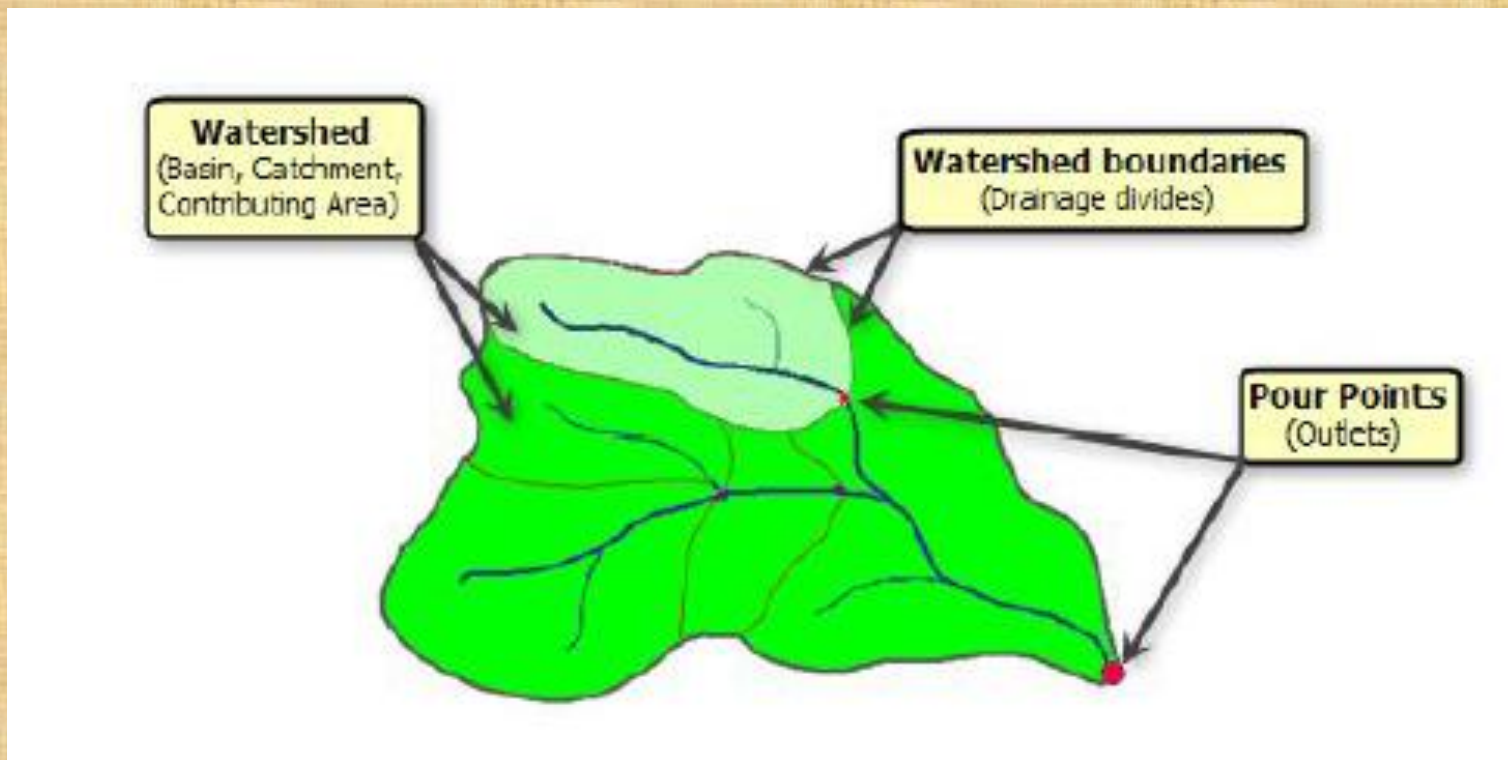
- Output coordinates
- Processing Extent: Union of input
- XY Resolution and Tolerance: resolution has to be mentioned



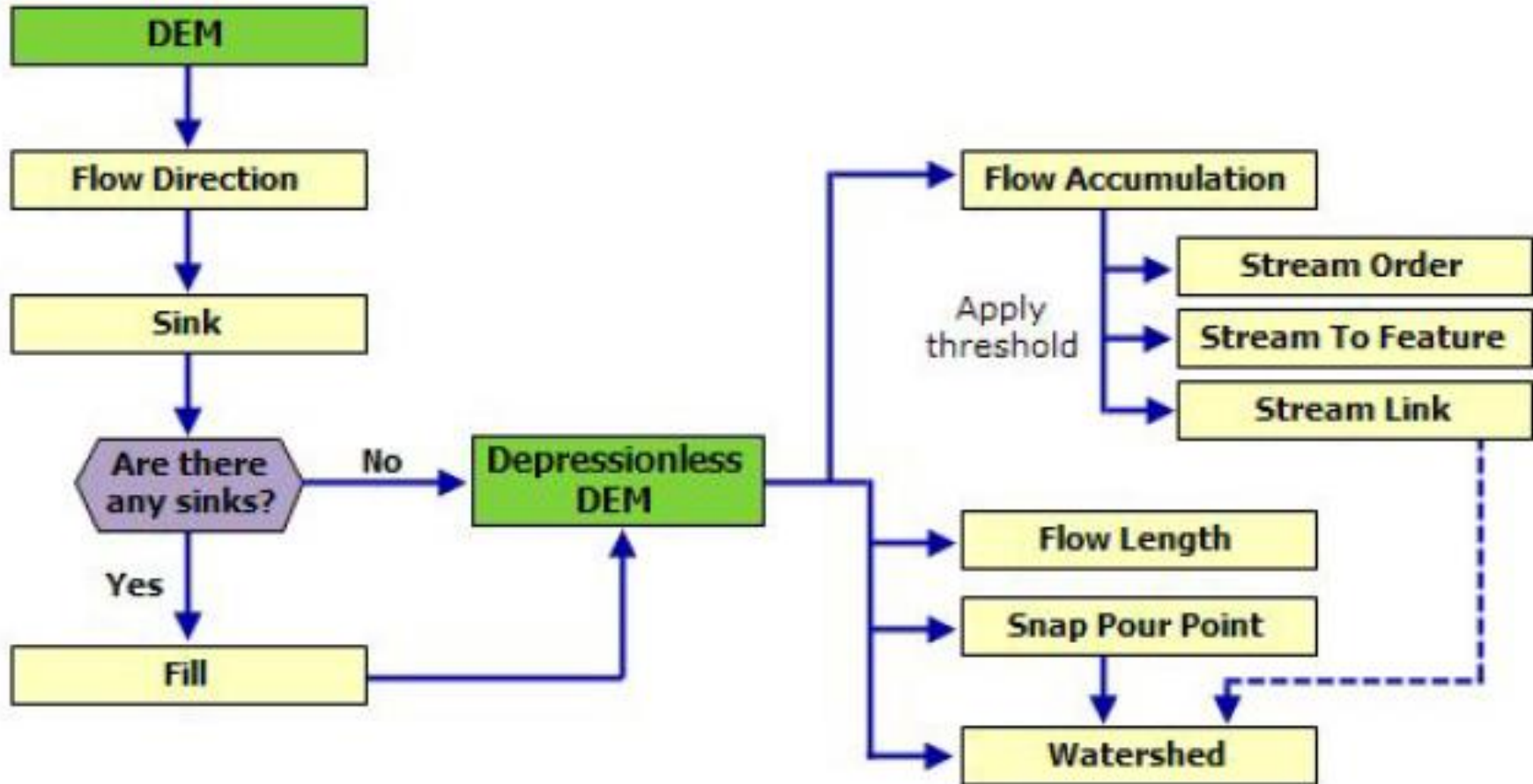
- **Spatial Analyst:** each function is available in ArcToolbox
- **Layers conversion:** ASCII, Raster, Shapefile, KLM
- **Interpolation:** IDW (Inverse Distance Weight), Linear Interpolation, Spline, Kriging
- **Surface:** Contour (isolines), Slope, Hillshade ...



- **Hydrology Tools:** they are used to model the flow of water across a surface. Information about the shape of the earth's surface is useful for many fields, such as regional planning, agriculture, and forestry

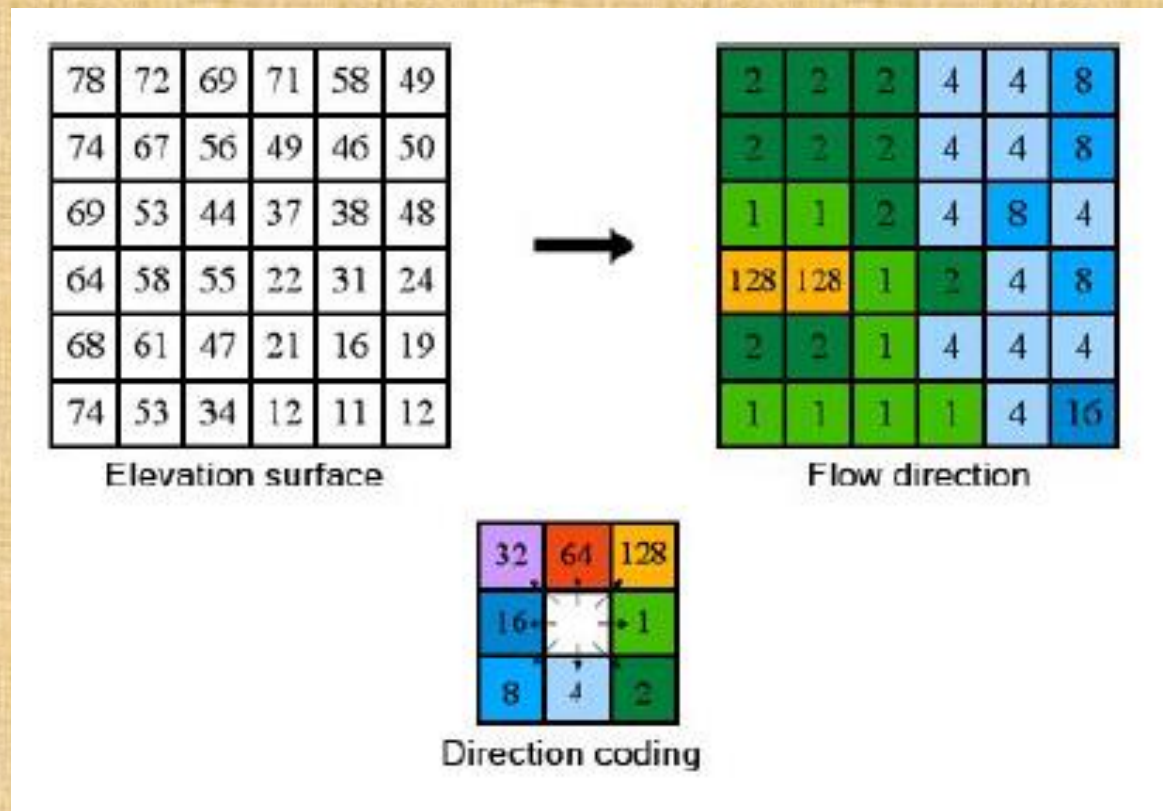


- How to obtain Watershed with the DEM using ArcGIS?



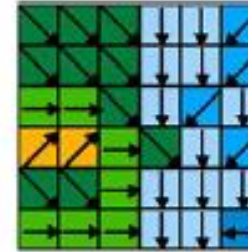
Hydrological modeling flowchart

- **Flow Direction:** creates a raster of flow direction from each cell to its steepest downslope neighbor



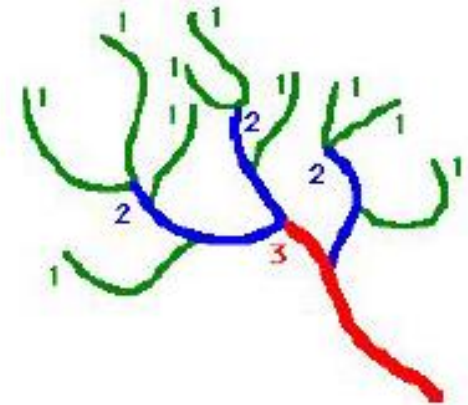
- **Fills sinks** in a surface raster to remove small imperfections in the data: ArcToolbox > Spatial Analyst > Fill

FLOW ACCUMULATION: creates a raster of accumulated flow into each cell based on Flow Direction



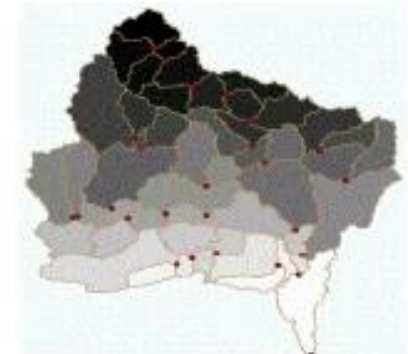
0	0	0	0	0	0
0	1	1	2	2	0
0	3	7	5	4	0
0	0	0	20	0	1
0	0	0	1	24	0
0	2	4	7	35	2

STREAM ORDER: assigns a numeric order to segments of a raster representing branches of a linear network

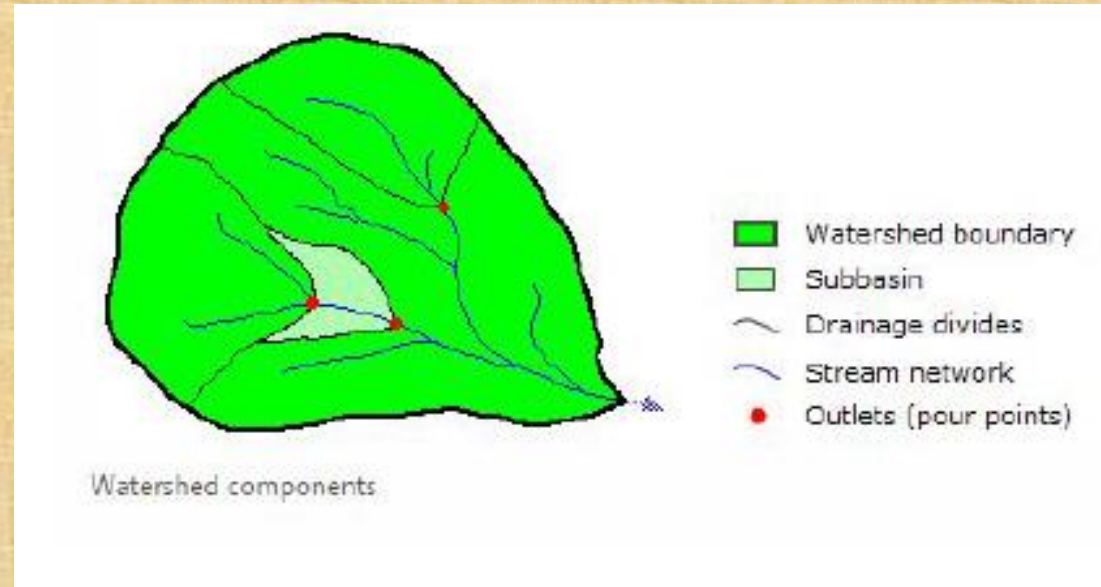


STREAM LINK: assigns unique values to sections of a raster linear network between intersections

POINT THE OUTLETS: by manual input or by using « snap pour points » tool



- **Watershed:** Determines the contributing area above a set of cells in a raster
 - Flow Direction Map
 - Pour point Location



- **Basin Function:** creates a raster delineating all drainage basins based on the Flow Direction

GIS data websites

- <http://seamless.usgs.gov/viewer.htm>
- <http://gisdata.usgs.gov>
- <http://edcsns17.cr.usgs.gov/EarthExplorer/>
- <http://data.geocomm.com/>

References

1. <http://webhelp.esri.com/arcgisdesktop/9.3/tutorials/tutorials.htm>
2. <http://libinfo.uark.edu/gis/tutorials/tutorial1.pdf>
3. http://webhelp.esri.com/arcgisdesktop/9.3/pdf/ArcCatalog_Tutorial.pdf
4. http://webhelp.esri.com/arcgisdesktop/9.3/pdf/ArcMap_Tutorial.pdf