Geographic Information Systems
An Introduction

Dr. Swarna Subba Rao

Former Surveyor General of India.

Adjunct Professor, NALSAR UNIVERSITY

HYDERABAD

Definition of GIS

What is GIS?

GIS = Geographic Information System

A GIS integrates hardware, software and data for **capturing**, **managing**, **analyzing**, and **displaying** all forms of geographically referenced information.

Definitions:

- The *common ground* between information processing and the many fields using spatial analysis techniques. (Tomlinson, 1972)
- A powerful *set of tools* for collecting, storing, retrieving, transforming, and displaying spatial data from the real world. (Burroughs, 1986)
- A computerised *database management system* for the capture, storage, retrieval, analysis and display of spatial (locationally defined) data. (NCGIA, 1987)
- A *decision support system* involving the *integration* of spatially referenced data in a problem solving environment. (Cowen, 1988)

An Intelligent Definition for GIS

*A system of integrated computer-based **tools** for end-to-end **processing** (capture, storage, retrieval, analysis, display) of data using **location on the earth's surface** for interrelation in support of **operations management, decision making, and science.***

- set of integrated tools for spatial analysis
- encompasses end-to-end processing of data
  - capture, storage, retrieval, analysis/modification, display
- uses explicit location on earth's surface to relate data
- aimed at decision support, as well as on-going operations and scientific inquiry

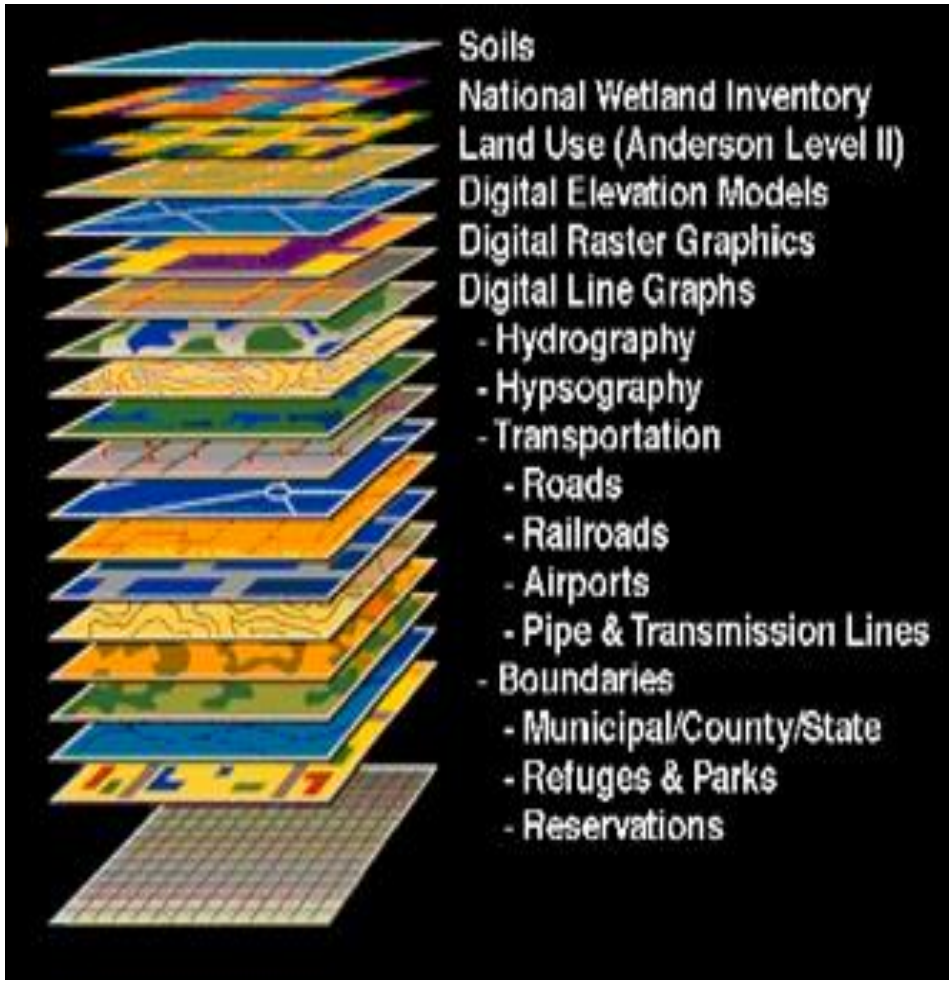
- ***Dr. Ronald Briggs***

Geographic Information System: *intuitive description*

- A map with a database behind it.
- A virtual representation of the real world and its infrastructure.
- A consistent "as-built" of the real world, natural and manmade

Which is

- *queried* to support *on-going operations*
- *summarized* to support *strategic decision making and policy formulation*
- *analyzed* to support *scientific inquiry*
- ***Dr. Ronald Briggs***



Why Study GIS?

- 80% of **provincial government** activities estimated to be geographically based
  - plants, zoning, public works (streets, water supply, sewers), garbage collection, land ownership and valuation, public safety (fire and police)
- a significant portion of **state government** has a geographical component
  - natural resource management
  - highways and transportation
- **Businesses** use GIS for a very wide array of applications
  - retail site selection & customer analysis
  - logistics: vehicle tracking & routing
  - natural resource exploration (petroleum, etc.)
  - precision agriculture
  - civil engineering and construction
- **Military and defense**
  - Battlefield management
  - Satellite imagery interpretation
- **Scientific research** employs GIS
  - geography, geology, botany
  - anthropology, sociology, economics, political science
  - Epidemiology, criminology

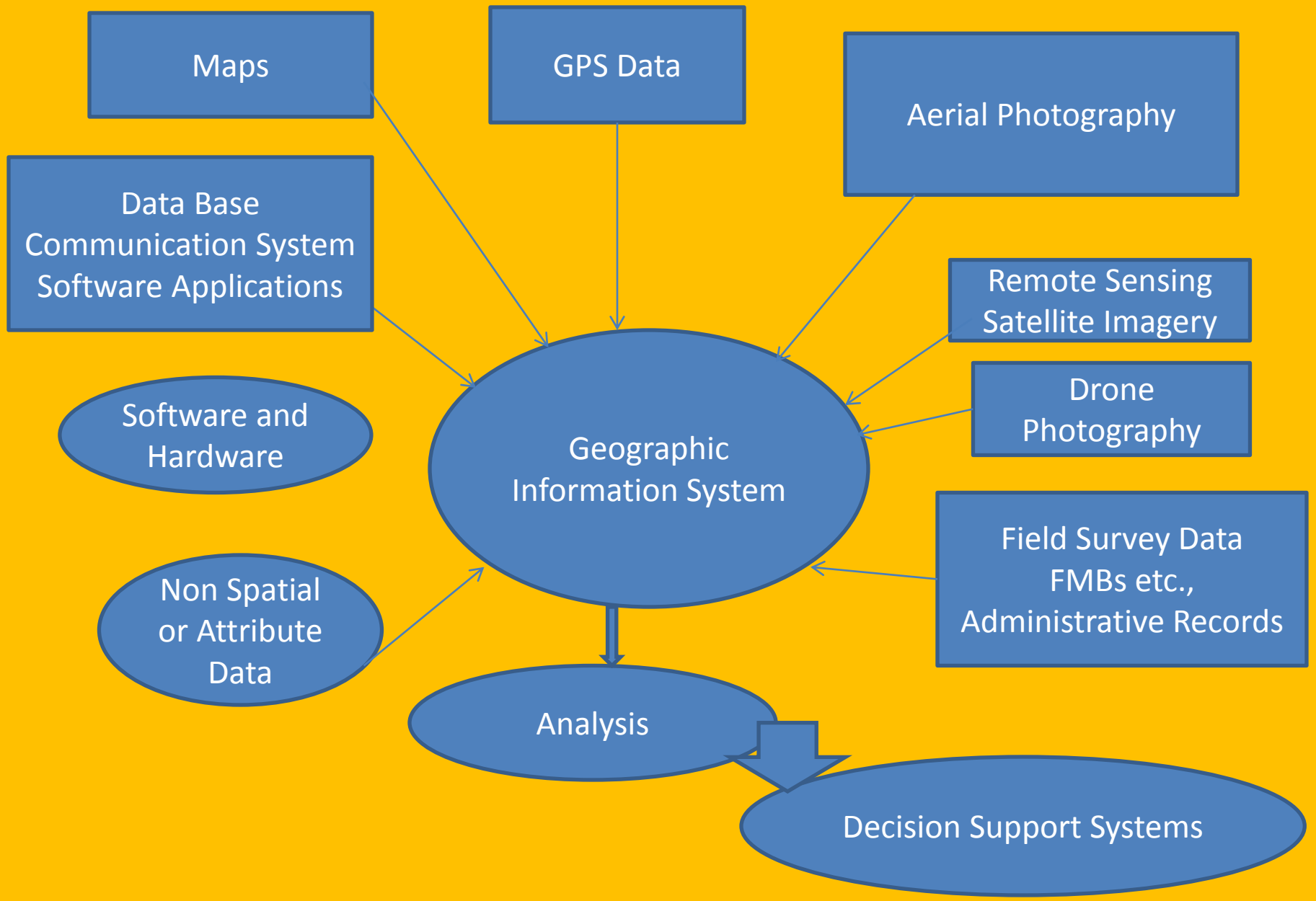
Examples of Applied GIS

- **Urban Planning, Management & Policy**
  - Zoning, subdivision planning
  - Land acquisition
  - Economic development
  - Code enforcement
  - Housing renovation programs
  - Emergency response
  - Crime analysis
  - Tax assessment
- **Environmental Sciences**
  - Monitoring environmental risk
  - Modeling storm water runoff
  - Management of watersheds, floodplains, wetlands, forests, aquifers
  - Environmental Impact Analysis
  - Hazardous or toxic facility siting
  - Groundwater modeling and contamination tracking
- **Political Science**
  - Redistricting
  - Analysis of election results
  - Predictive modeling
- **Civil Engineering/Utility**
  - Locating underground facilities
  - Designing alignment for freeways, transit
  - Coordination of infrastructure maintenance
- **Business**
  - Demographic Analysis
  - Market Penetration/ Share Analysis
  - Site Selection
- **Education Administration**
  - Attendance Area Maintenance
  - Enrollment Projections
  - School Bus Routing
- **Real Estate**
  - Neighborhood land prices
  - Traffic Impact Analysis
- **Health Care**
  - Epidemiology
  - Needs Analysis
  - Service Inventory

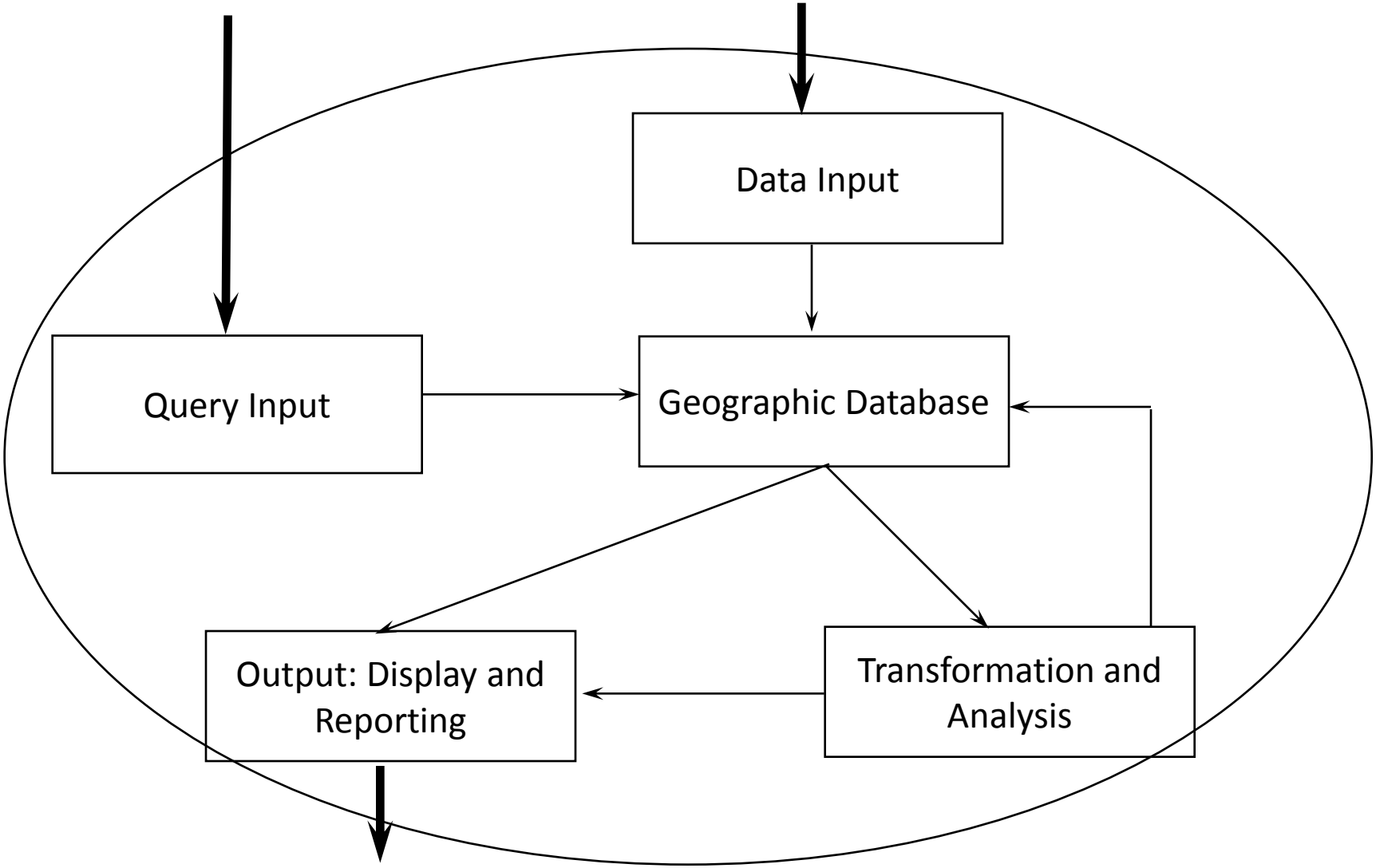
What GIS Applications Do:
manage, analyze, communicate

- make possible the **automation** of activities involving geographic data
  - map production
  - calculation of areas, distances, route lengths
  - measurement of slope, aspect, volumes
  - logistics: route planning, vehicle tracking, traffic management
- allow for the **integration** of data hitherto confined to independent domains (e.g property maps and air photos).
- by tying data to maps, permits the succinct **communication of complex spatial patterns** (e.g environmental sensitivity).
- provides answers to **spatial queries** (how many elderly in Richardson live further than 10 minutes at rush hour from ambulance service?)
- perform complex **spatial modelling** (*what if* scenarios for transportation planning, disaster planning, resource management, utility design)

Geographic Information System

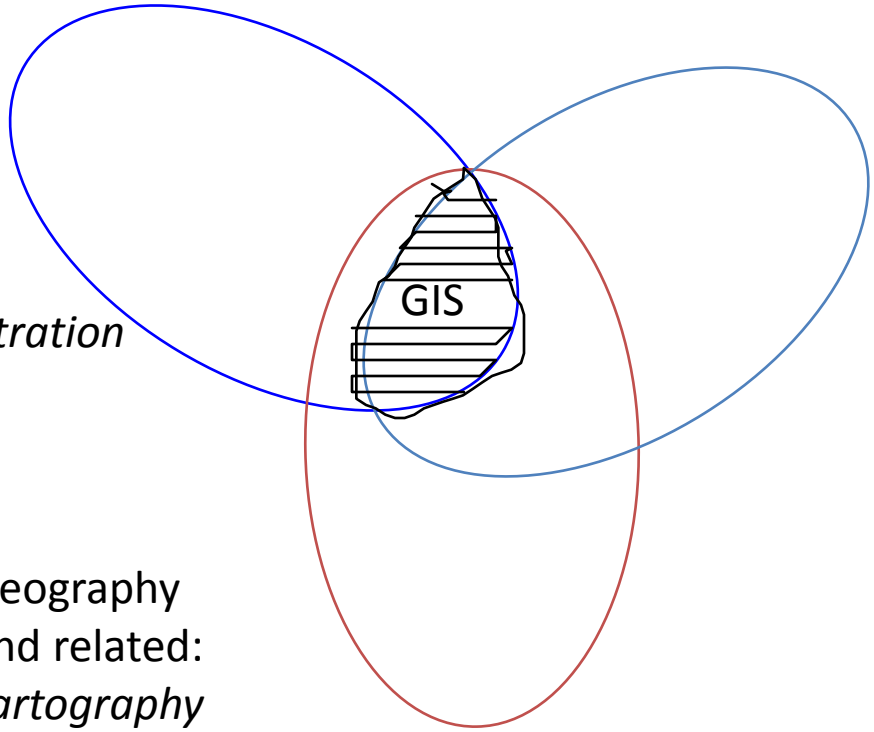


GIS System Architecture and Components



Knowledge Base for GIS

Computer Science/MIS
graphics
visualization
database
system administration
security



Application Area:
public admin.
planning
geology
mineral exploration
forestry
site selection
marketing
civil engineering
criminal justice
surveying

Geography and related:
cartography
geodesy
photogrammetry
landforms
spatial statistics.

The convergence of technological fields and traditional disciplines.

The major areas of GIS application

- Local Government
  - Public works/infrastructure management (roads, water, sewer)
  - Planning and environmental management
  - property records and appraisal
- Real Estate and Marketing
  - Retail site selection, site evaluation
- Public safety and defense
  - Crime analysis, fire prevention, emergency management, military/defense
- Natural resource exploration/extraction
  - Petroleum, minerals, quarrying
- Transportation
  - Airline route planning, transportation planning/modeling
- Public health and epidemiology
- The Geospatial Industry
  - Data development, application development, programming

MAPS - SOURCE OF GEOSPATIAL DATA

- Type: Topographic, Cadastral, Thematic, Special Purpose, Tourist and Guide Maps.
- Scale: 1:1000 etc to 1:1000000.
- Form: Paper, Digital, Image Maps.
- Map is the most basic INFRASTRUCTRAL TOOL in planning.
- Map is the oldest GIS package.

PAPER MAPS Vrs DIGITAL MAPS

- Paper Maps.
- Oldest .
- Legacy data.
- Easy to understand.
- Limited Attribute Information
- Editing difficult.
- Survey and Mapping is expensive and time consuming.
- Scale

- Digital Maps.
- Computer Based
- Easy to edit.
- Easy to Reproduce.
- Easy to convert format or export or copy.
- Layers are possible.
- Fit for integration with other data.
- Resolution.

PHOTOGRAPHY Vrs REMOTE SENSING

- Photography
- Aircraft, drones, UAVs
- Photogrammetric methods
- Flying height limited
- Weather dependent.
- Drones are suitable for small areas and short notice
- Metric Quality

- Remote sensing Imagery
- Satellite based
- High altitude
- SAR, Infra red etc techniques for cloud penetration
- Suitable for large areas in short duration
- Interpretation intensive

AERIAL PLATFORMS

- Air Photography: Ortho and Oblique.
- Flying Aircraft.
- Highrise buildings
- Drones

Other Aspects

- Areal Camera.
- Photogrammetry.
- Analog Plotters.
- Analytical Photogrammetry.
- Mapping using Air Photography.

REMOTE SENSING

- Satellite Imagery.
- Quality of Imagery with respect to function.
- High Resolution Satellite Imagery.
- Various Types of Imagery. PAN Chromatic, Mono Chromatic, SAR, RADAR etc..
- Google

Data Representation (Vector)

A coordinate-based data model that represents geographic features as points, lines, and polygons.

1. Points

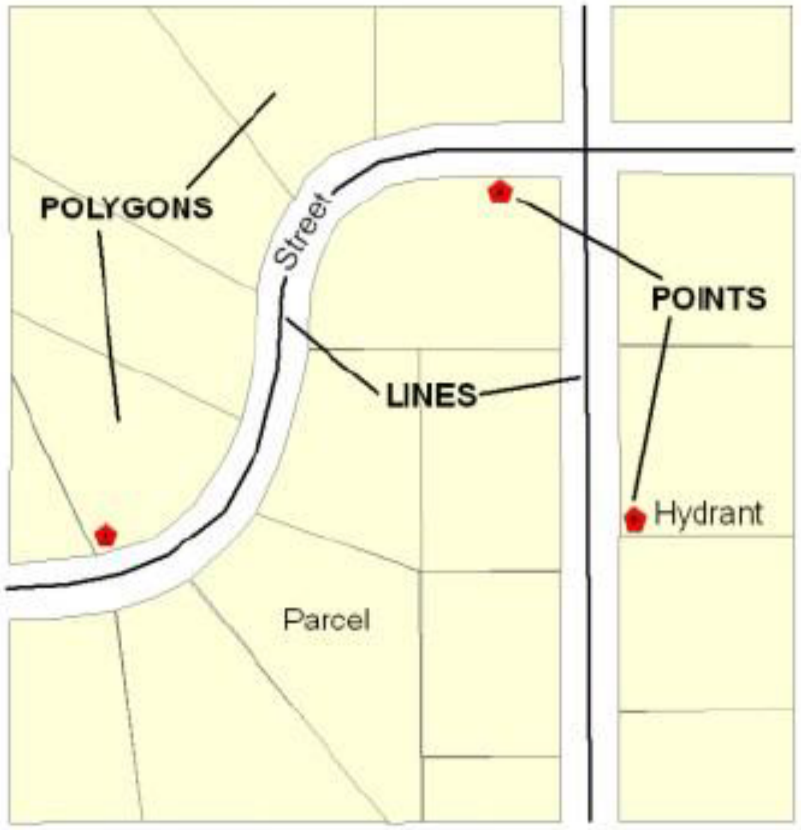
Location of Wells, Schools, or Points of Interest

2. Lines / Polylines

Road Centerlines, Rivers, Trails, or Streets

3. Polygons

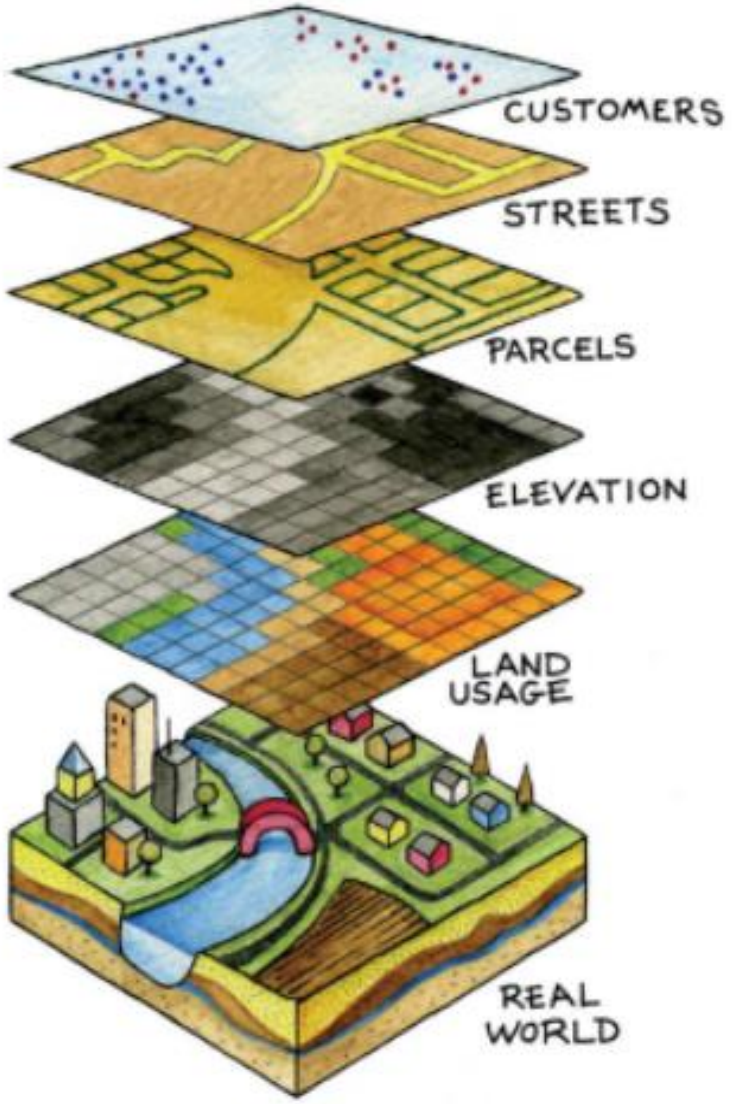
Boundary of Cities, Lakes, or Forests



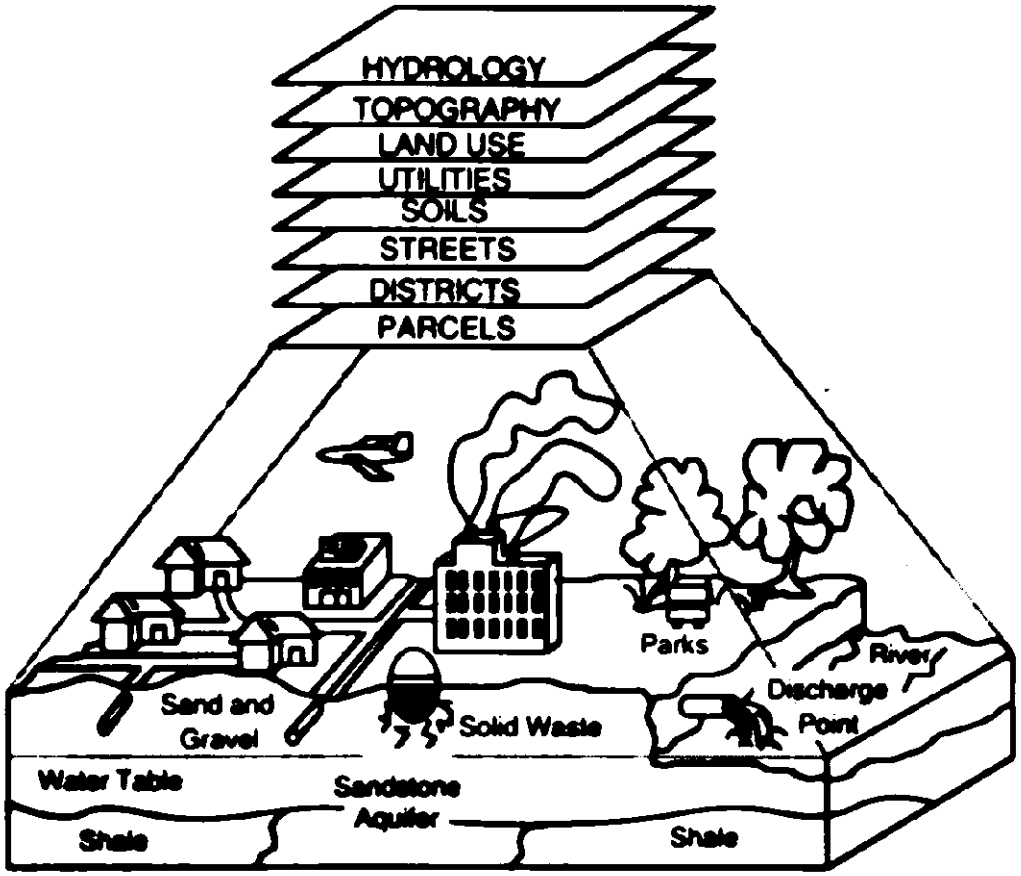
Data Representation

- GIS data represents **real world objects** (e.g. roads, land use, elevation, trees, waterways, etc.)

- There are 2 broad methods used to store data in GIS
  1. **Vector** data model
  2. **Raster** data model



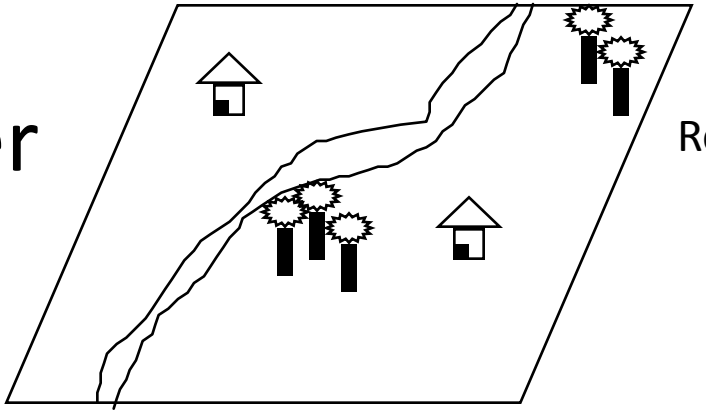
A layer-cake of information



A number of related data layers can represent the many geographies of the real world.

GIS Data Model

Concept of Vector and Raster

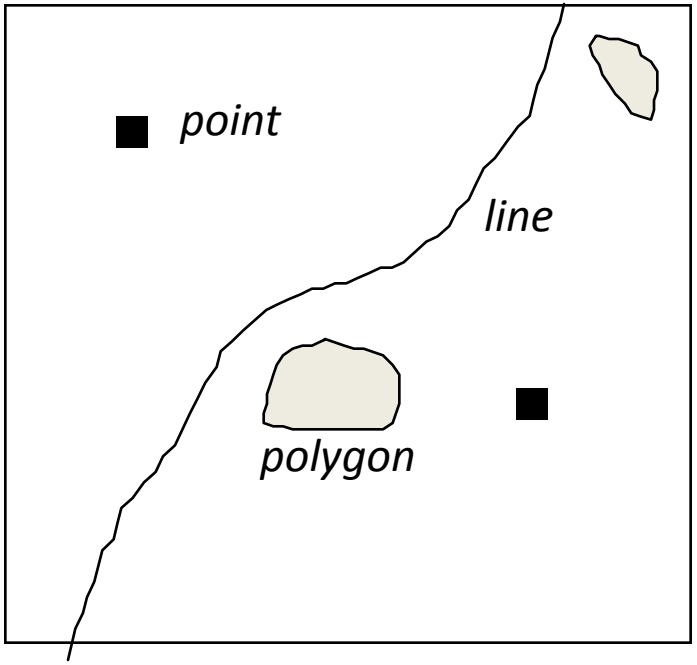


Real World

Raster Representation

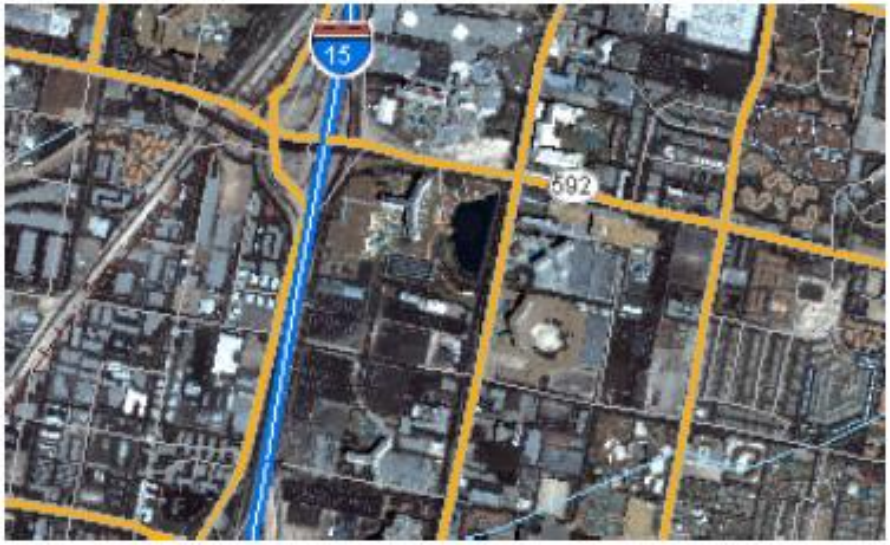
	0	1	2	3	4	5	6	7	8	9
0								R	T	
1							R			T
2		H					R			
3							R			
4					R	R				
5				R						
6			R		T	T		H		
7			R		T	T				
8		R								
9		R								

Vector Representation

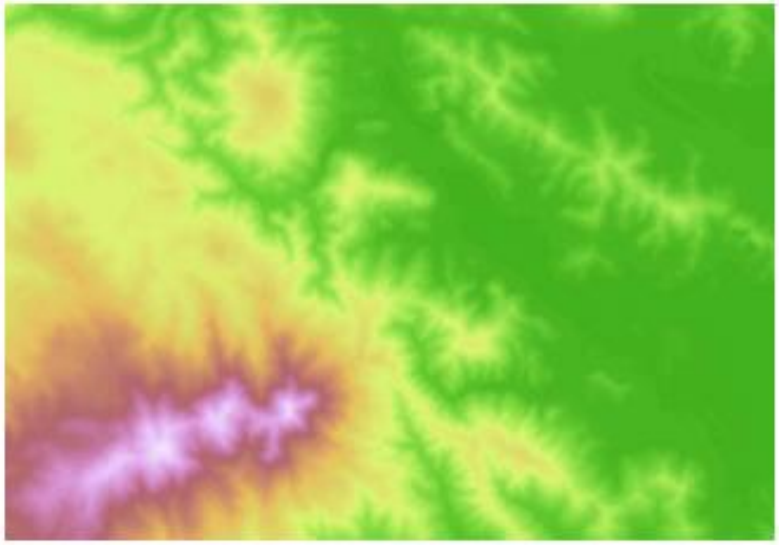


Data Representation (Raster)

A spatial data model that defines space as an **array of equally sized cells** arranged in rows and columns. Each cell contains an **attribute value** and **location coordinates**.



Raster as Satellite Imagery



Raster as Elevation Surface

Representing Data with *Raster* and *Vector* Models

Raster Model

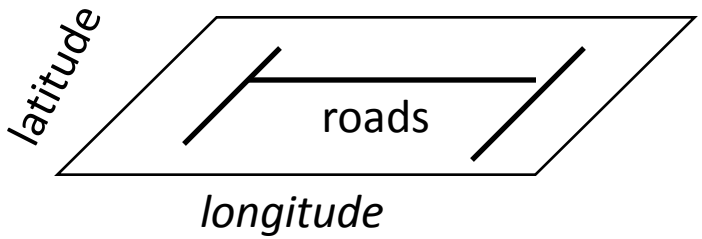
- area is covered by grid with (usually) equal-sized, square cells
- attributes are recorded by assigning each cell a single value based on the majority feature (attribute) in the cell, such as land use type.
- *Image* data is a special case of raster data in which the "attribute" is a reflectance value from the geomagnetic spectrum
  - cells in image data often called *pixels* (picture elements)
- **Vector Model**

The fundamental concept of vector GIS is that all geographic features in the real work can be represented either as:

- **points or dots (*nodes)***: trees, poles, fire plugs, airports, cities
- **lines (*arcs)*:** streams, streets, sewers,
- **areas (*polygons)*:** land parcels, cities, counties, forest, rock type

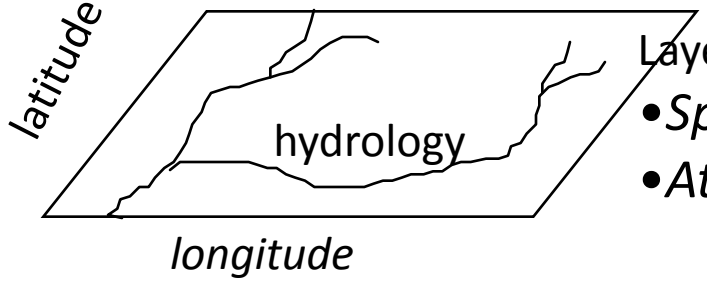
Because representation depends on shape, ArcView refers to files containing vector data as *shapefiles*

The GIS Model: example



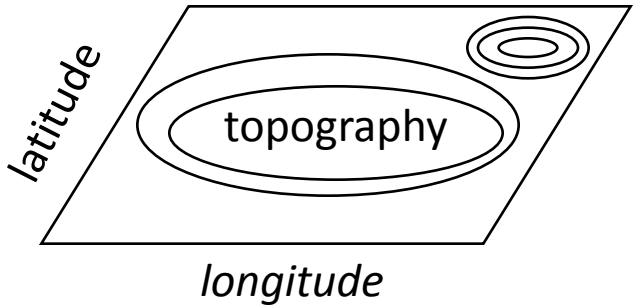
Here we have three layers or themes:
--roads,
--hydrology (water),
--topography (land elevation)

They can be related because precise geographic coordinates are recorded for each theme.



Layers are comprised of two data types
- *Spatial data* which describes location (where)
- *Attribute data* specifing what, how much,when

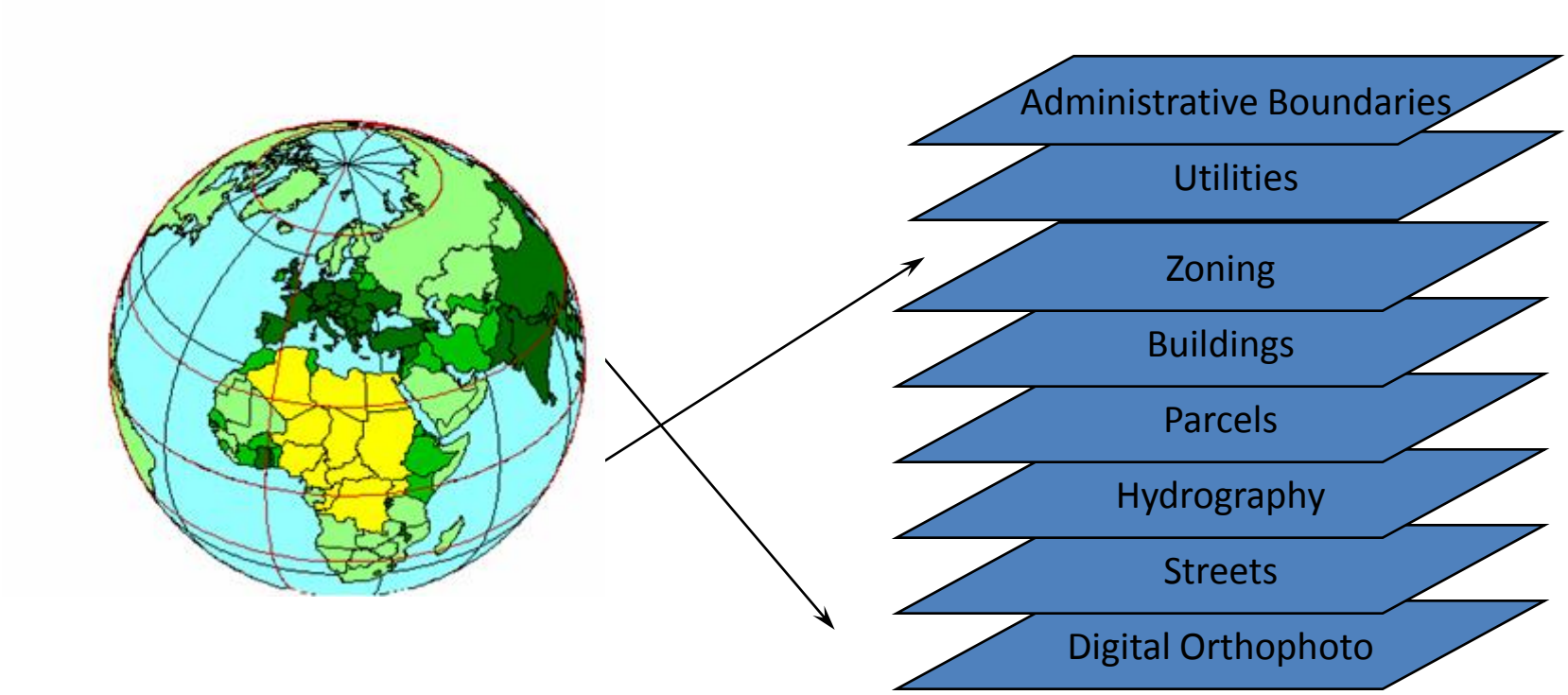
Layers may be represented in two ways:
- in *vector* format as points and lines
- in *raster(or image)* format as pixels



All geographic data has 4 properties:
projection, scale, accuracy and resolution

The GIS Data Model: Implementation

Geographic Integration of Information



- Data is organized by layers, coverages or themes **(**synonomous concepts)*, with each layer representing a common feature.*
- Layers are integrated using explicit location on the earth's surface, *thus geographic location is the organizing principal*.

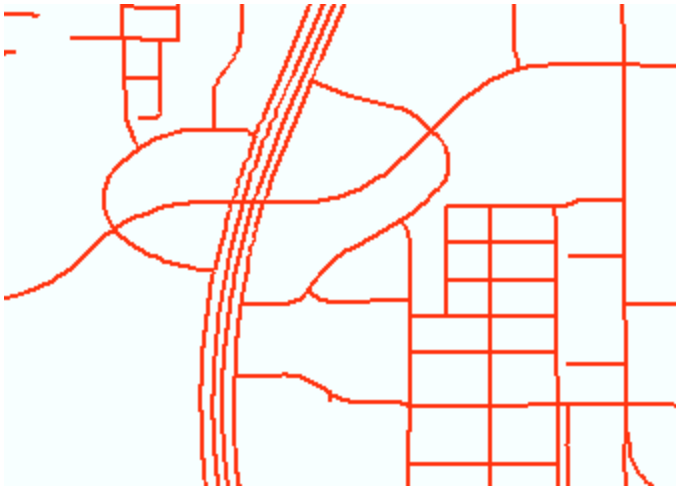
Spatial and Attribute Data

- Spatial data *(where)*
  - specifies location
  - stored in a *shape file, geodatabase* or similar geographic file
- Attribute (descriptive) data *(what, how much, when)*
  - specifies characteristics at that location, natural or human-created
  - stored in a data base *table*

GIS systems traditionally maintain spatial and attribute data separately, then "join" them for display or analysis

- for example, in ArcView, the *Attributes of …* table is used to link a *shapefile* (spatial structure) with a *data base table* containing attribute information in order to display the attribute data spatially on a map

Layers



Vector Layers

Street Network layer: lines

Land Parcels layer: polygons

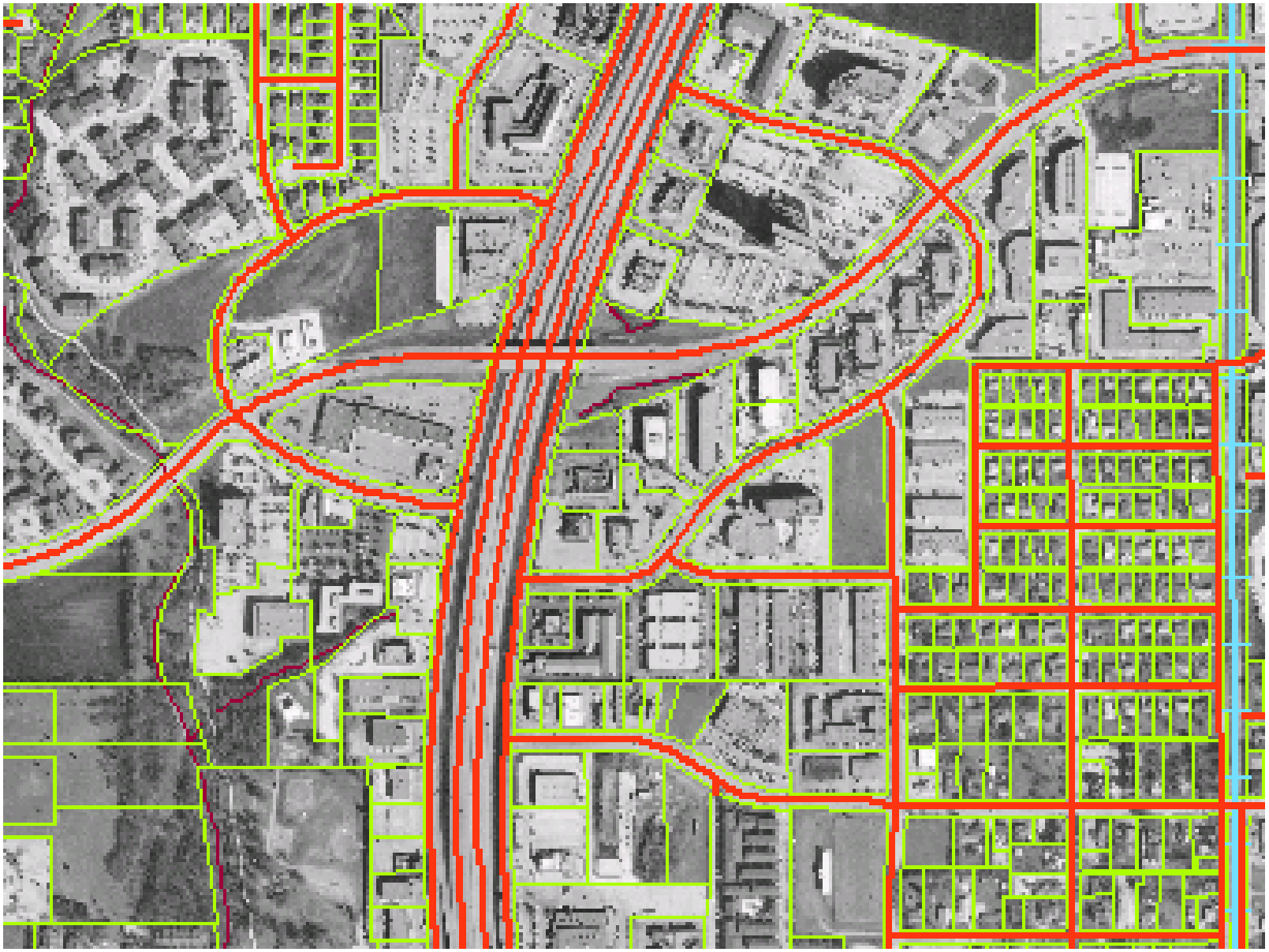
Raster (image) Layer

Digital Ortho Photograph Layer:

Digital Ortho photo: *combines the visual properties of a photograph with the positional accuracy of a map, in computer readable form.*

Projection: State Plane, North Central Texas Zone, NAD 83
Resolution: 0.5 meters
Accuracy: 1.0 meters
Scale: see scale bar

Overlay based on Common Geographic Location

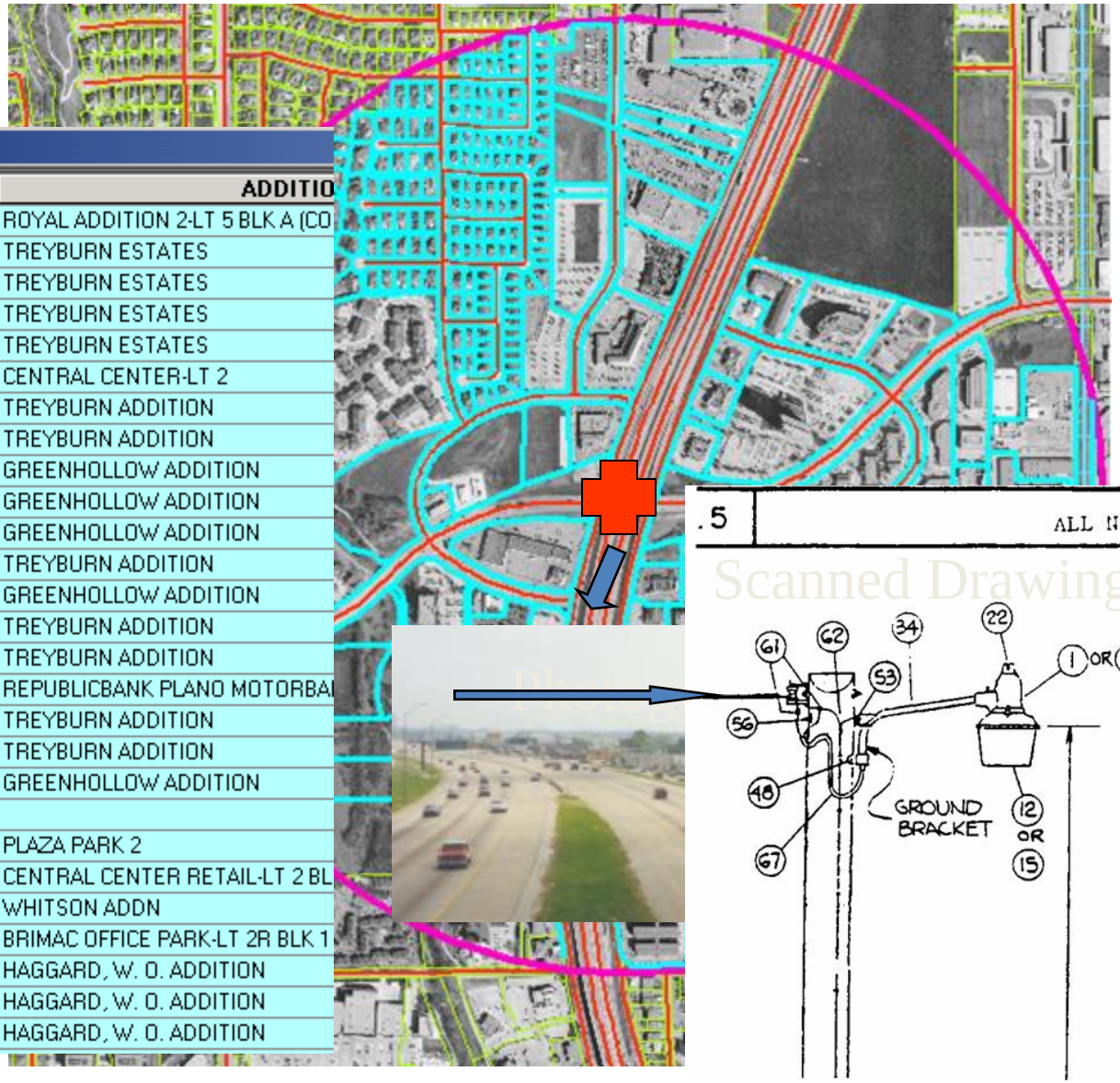


Analysis

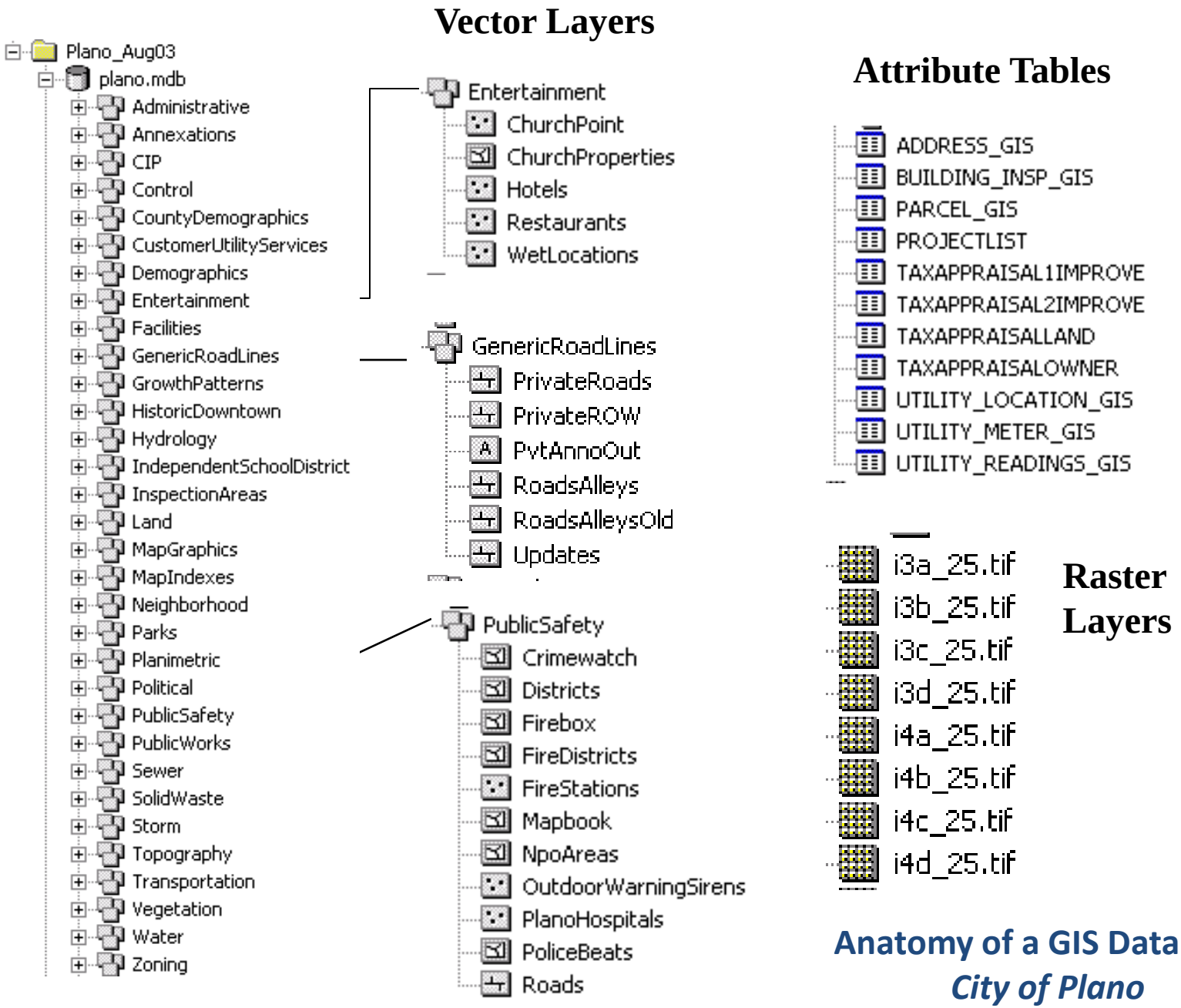
Data Table

Selected Attributes of Parcels

OBJECTID*	TAXID	LANDKEY*	ADDITIO
48926	R404100A00501	297700A00501	ROYAL ADDITION 2-LT 5 BLK A (CO
49447	R274100C00301	057200C00301	TREYBURN ESTATES
49783	R274100C01301	057200C01301	TREYBURN ESTATES
49804	R274100C01101	057200C01101	TREYBURN ESTATES
50309	R274100A01801	057200A01801	TREYBURN ESTATES
51407	R191500100201	241600100201	CENTRAL CENTER-LT 2
51844	R236500D00601	046100D00601	TREYBURN ADDITION
51846	R236500D00501	046100D00501	TREYBURN ADDITION
51950	R020200508101	015500508101	GREENHOLLOW ADDITION
51951	R020200501901	015500501901	GREENHOLLOW ADDITION
51980	R020200507801	015500507801	GREENHOLLOW ADDITION
52091	R236500D00801	046100D00801	TREYBURN ADDITION
52297	R020200500801	015500500801	GREENHOLLOW ADDITION
52448	R236500A01401	046100A01401	TREYBURN ADDITION
52471	R236500A01501	046100A01501	TREYBURN ADDITION
52778	R139500100101	227900100101	REPUBLICBANK PLANO MOTORBA
53343	R236500B00801	046100B00801	TREYBURN ADDITION
53555	R236500A00701	046100A00701	TREYBURN ADDITION
53564	R020200500201	015500500201	GREENHOLLOW ADDITION
53664	R621200000401	621200000401	
54453	R139900100101	228200100101	PLAZA PARK 2
54753	R196200A00201	243000A00201	CENTRAL CENTER RETAIL-LT 2 BL
55417	R240300100101	256100100101	WHITSON ADDN
55478	R193000100201	241900100201	BRIMAC OFFICE PARK-LT 2R BLK 1
55704	R021000300101	002200300101	HAGGARD, W. O. ADDITION
55717	R021000400401	002200400401	HAGGARD, W. O. ADDITION
56018	R021000300901	002200300901	HAGGARD, W. O. ADDITION



Parcels within a half mile buffer of Park and Central



Anatomy of a GIS Database:
City of Plano

Software for GIS: *The Main Players*

- **ESRI, Inc.,** Redlands, CA
  - clear market leader with about a third of the market
  - originated commercial GIS with their ArcInfo product in 1981
  - privately owned by Jack Dangermond, a legend in the field
  - Strong in gov., education, utilities and business logistics
- **MapInfo, Troy N.Y.**
  - Aggressive newcomer in early 1990s, but now well-established.
  - Strong presence in business, especially site selection & marketing, and telecom
- **Intergraph** (Huntsville, AL)
  - origins in proprietary CAD hardware/software
  - Older UNIX-based **MGE** (Modular GIS Environment) evolved from CAD
  - Current **GeoMedia** was the first true MS Windows-based GIS
  - strong in design, public works, and FM (facilities management), but weakening
- **Bentley Systems** (Exton, PA)
  - **MicroStation GeoGraphics,** originally developed with Intergraph, is now their exclusive and main product..
  - Strong in engineering; advertises itself as "geoengineering"
- **Autodesk** (San Rafael, CA)
  - Began as PC-based CAD, but now the dominant CAD supplier
  - First GIS product **AutoCAD *Map*** introduced in 1996
  - Primarily small business/small city customer base

The main two "pure GIS" companies.

Software for GIS: other players

Vector GIS

- **Smallworld Systems** (Englewood, CO)
  - first to use OO (early '90s), but failed to compete as established vendors did same
  - Purchased by GE in 2000
  - emphasis on FM & utilities
- **Manifold** (CDA International Corp):
  - low cost, but low market share
- **Maptitude** (Caliper Corp, Newton, MA):
  - another low cost one

Raster GIS

- **ERDAS/Imagine**
  - long established leader
  - acquired by Leica Geosystems in 2001
- **ER MAPPER**
  - aggressive newcomer originating in Australia
- **Envi,**
  - relative newcomer, radar specialization
  - acquired by Kodak in 2000
- **PCI**--Geomatica
  - long-term Canadian player
- **CARIS**
  - newer Canadian entry
- **GRASS** (Rutgers Univ.)
  - Classic old-timer originally developed by US Army Construction Engineering Research Lab(CERL) in Champaign, IL;
  - army ended dev. & support in 1996 but assumed by Baylor University.
- **IDRSI** (Clark Univ)
  - pioneering, university-developed package

ESRI Product Line-up: *ArcGIS* client products (Fall 2007)

ArcReader ("adobe acrobat" for maps) & **ArcExplorer** (spatial data viewer)

- Free viewers for geographic data.

ArcGIS 9.x Desktop: two primary modules (MS only)

1. **ArcMap:** for data display, map production, spatial analysis, data editing
2. **ArcCatalog:** for data management and preview

ArcToolbox, for specialized data conversions and analyses, available as a window in both

Available capabilities within these modules are "tiered" in three levels

- **ArcView:** viewing, map production, spatial analysis, basic editing:
- **ArcEditor:** ArcView, plus specialized editing:
- **ArcInfo:** ArcView & ArcEditor plus special analyses and conversions:

Extensions: for special apps.: *Spatial Analyst, 3D Analyst, Geostatistics, Business Analyst, etc.*

ArcObjects: to build specialized capabilities within ArcMap or ArcCatalog using VB for Applications

ArcGIS Workstation (for UNIX and MS)

- the old command line ArcInfo 7.1

ArcGIS Engine (MS NT/2000/XP)

- Set of embeddable GIS components (ArcObjects software objects) for use in building custom applications
- Runs under Windows, Unix and Linux, with support for Java, C++, COM and .NET
- Replaces MapObjects which were based upon a previous generation of GIS objects

Notes:

ArcView 3.3 the only GUI option for UNIX.

ArcGIS 8 released 2000 to integrate two previous standalone products: ArcView and ArcInfo

ArcGIS 9 released 2004 providing the full capability that should have been in ArcGIS 8!!!

--full support for all data types (coverages, shapefiles, geodatabases)

--full support for all previous geoprocessing analyses

--Modelbuilder for scripting and repetitive processing

--ArcEngine for building custom applications

ESRI Product Line-up: *ArcGIS* server products (Fall 2007)

ArcGIS Server: three tiers of capability

Data services: ArcSDE (Spatial Database Engine)

- middleware to support spatial data storage in standard DBMS on server
- Supports all major industry databases:
  - Oracle, SQL-Server, IBM DB2, Ingres

Map services: ArcIMS (Internet Map Server)

- Provides maps and simple query to a user without a desktop GIS
- Accessed via web interface

Analytic services:

- Permits the creation of server-based specialized GIS applications
- Provides full range of GIS capabilities to a user without a desktop GIS
- Accessed via web interface

(prior to 9.2 these were sold as three separate products)

ArcGIS On-line Services

- On-line services made available on the Internet with a subscription
- Normally charged on a "per transaction" basis, but can be flat fee
- built and operated by ESRI (or other others), usually based on ArcGIS Server

Geodatabase (ArcSDE)

- ArcSDE = **Spatial Database Engine**
- Core component of ArcGIS for Server
- Primary data storage model for ArcGIS
- **Centralized** location to access and manage spatial data
- Major Features
  - Versioning
  - Geodatabase Replication
  - Geodatabase Archiving
- Support **Microsoft SQL Server**, **Oracle**, etc.

ESRI ArcGIS for Desktop

ArcMap

- **View**, **Edit** and **Query** geospatial data, and **Create Maps**

ArcCatalog

- **Manage** geospatial data
- **Browse** datasets, files, database or other sources

Joey Li

Thank you.

My Mobile No. 9963923480

Email: srswarna@gmail.com