

# Spatial Tools in Water Resource Management

Susan Steele-Dunne  
Nick van de Giesen  
Olivier Hoes  
Wim Bastiaanssen

## 1. Introduction to GIS

# Course Introduction: Learning objectives

**By the end of this course, you will be able to:**

- 1) Explain what a GIS is, and to describe its key features
- 2) Use GIS to map and analyze data
- 3) Use GIS spatial analyst toolbox to work on real WRM problems
- 4) Understand important terminology in remote sensing
- 5) Explain the advantages and disadvantages of measurements in different parts of the EM spectrum
- 6) Use real remote sensing data to study problems in WRM

# Course Introduction: People

Lecture	Contact person
Introduction to GIS	Susan Steele-Dunne
Spatial Analysis in GIS	Susan Steele-Dunne & Olivier Hoes
Watershed Delineation	Susan Steele-Dunne
Introduction to Remote Sensing & Visible RS	Nick van de Giesen
Thermal IR Remote Sensing	Wim Bastiaanssen
Microwave Remote Sensing	Susan Steele-Dunne

# Course Introduction: Blackboard

- Lecture notes
- Collegerama/vodcasts
- Assignment instructions data and submission
- Grade Center
- Announcements
- **Discussion Board** (New thread for each module)



# Course Introduction: Assignments

Submit assignments via **Blackboard**.

Turn in a report as a **pdf** file

## **Filename:**

Assignment1\_YourName\_StudentNumber.pdf  
(e.g. Assignment1\_Steele-Dunne\_123456.pdf)

Assignment is due at **8am** on the due date.  
10% per day penalty for late assignments.

# CT5401 – Lecture 1

## Introduction to GIS

- What is GIS?
- Data models to represent our world
- Functions of a GIS
- Real applications of GIS in Hydrology and Water Resources Management
- Introduction to Assignment 1

# CT5401 – Lecture 1

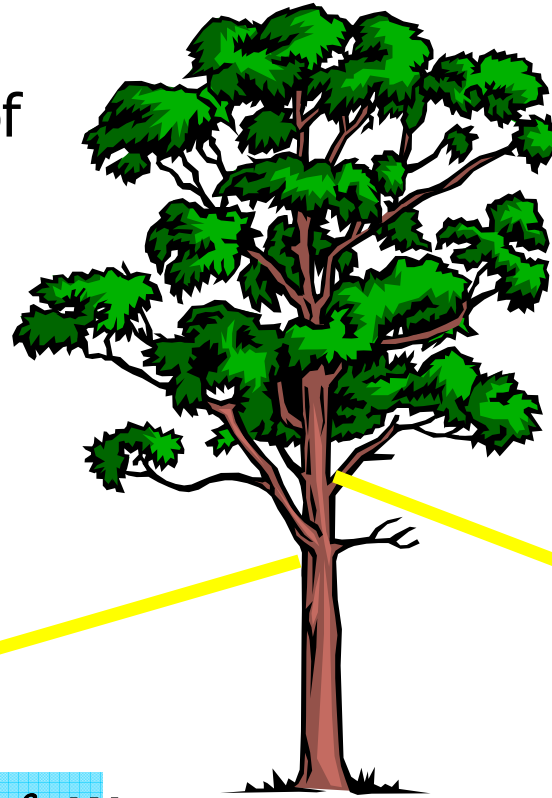
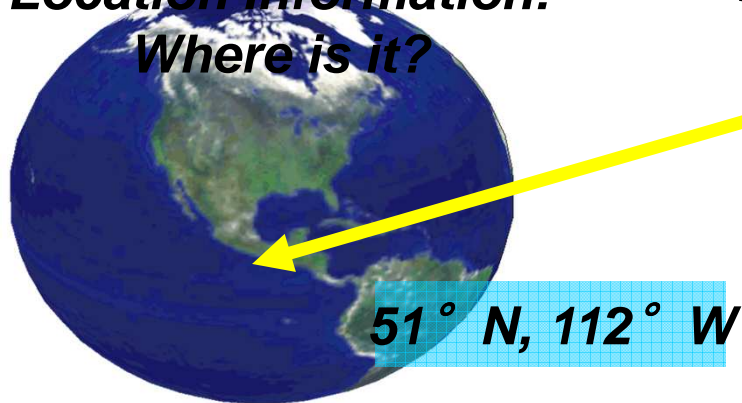
## Introduction to GIS

- **What is GIS?**
- Data models to represent our world
- Functions of a GIS
- Real applications of GIS in Hydrology and Water Resources Management
- Introduction to Assignment 1

# What is a GIS?

We can describe any element of our world in **two** ways:

**Location Information:**  
*Where is it?*



[1]

**Attribute Information:**  
*What is it?*

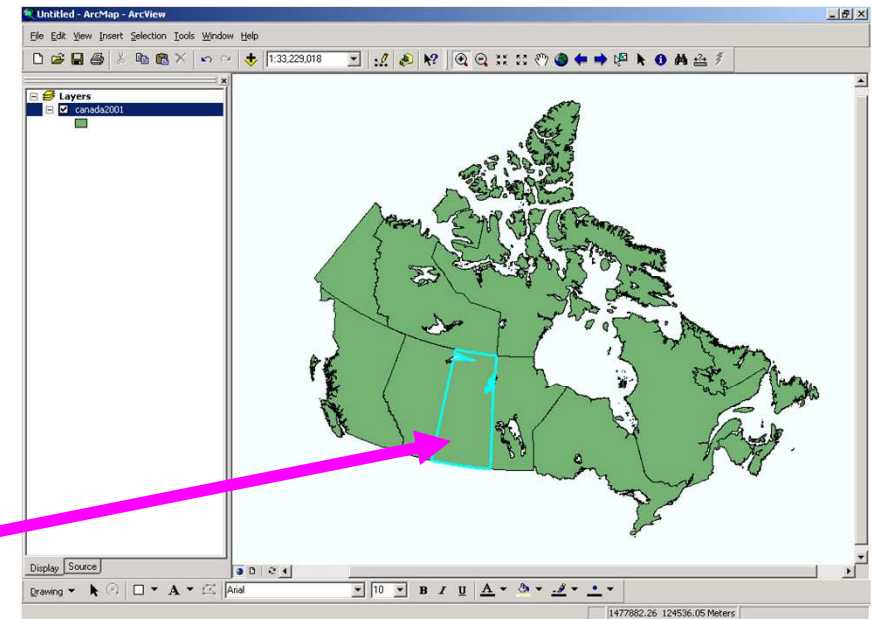
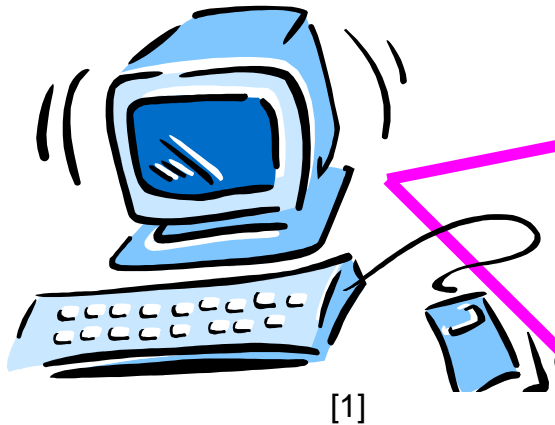
Species: Oak  
Height: 15m  
Age: 75 Yrs  
Condition:  
Good



# What is a GIS

GIS links datasets

GIS software links the location data and the attribute data:



Attributes of canada2001								
FID	Shape*	KEY	NAME	NOM	POP_2001	DWELL_2001	PI	
0	Polygon	4800000	Alberta	Alberta	2789528	984275		
1	Polygon	5900000	British Columbia	Colombie-Britannique	3907738	1643969		
2	Polygon	4600000	Manitoba	Manitoba	1119583	477085		
3	Polygon	1300000	New Brunswick	Nouveau-Brunswick	729498	313609		
4	Polygon	1000000	Newfoundland and Labrador	Terre-Neuve	512930	227570		
5	Polygon	1200000	Nova Scotia	Nouvelle-cosse	908007	403819		
6	Polygon	3500000	Ontario	Ontario	11410046	4556240		
7	Polygon	1100000	Prince Edward Island	le-du-Prince-douard	137312	48630		
8	Polygon	2400000	Quebec	Québec	7237479	3230196		
9	Polygon	4700000	Saskatchewan	Saskatchewan	978933	431628		
10	Polygon	6000000	Yukon	Yukon	28674	13793		
11	Polygon	6200000	Northwest Territories	Territoires du Nord-Ouest	26745	8177		
12	Polygon	6100000	Nunavut	Nunavut	37360	14669		

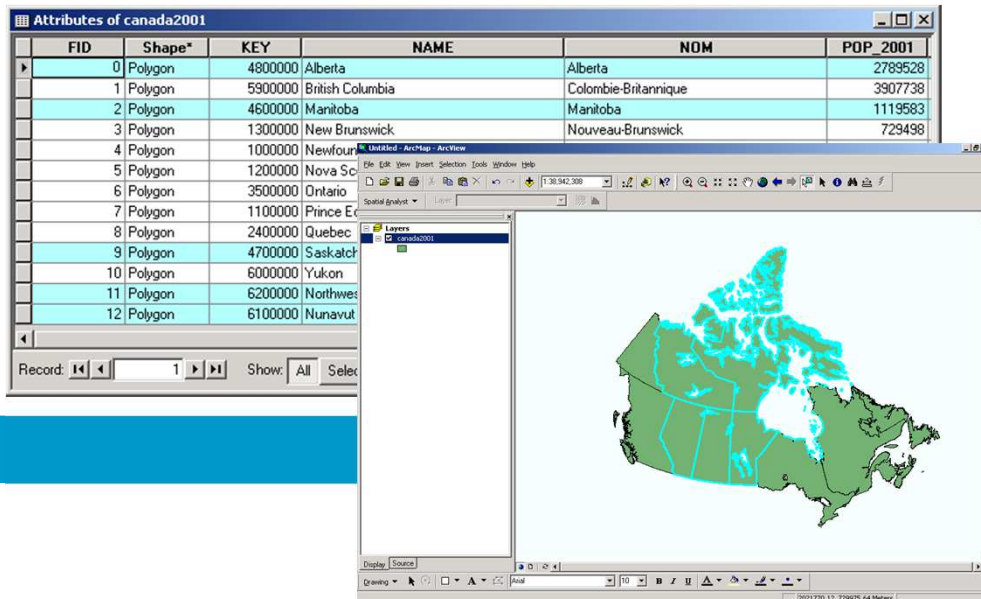
Record: 1 Show: All Selected Records (1 out of 13 Selected.) Options

# What is a GIS?

**GIS software can answer questions about our world:**

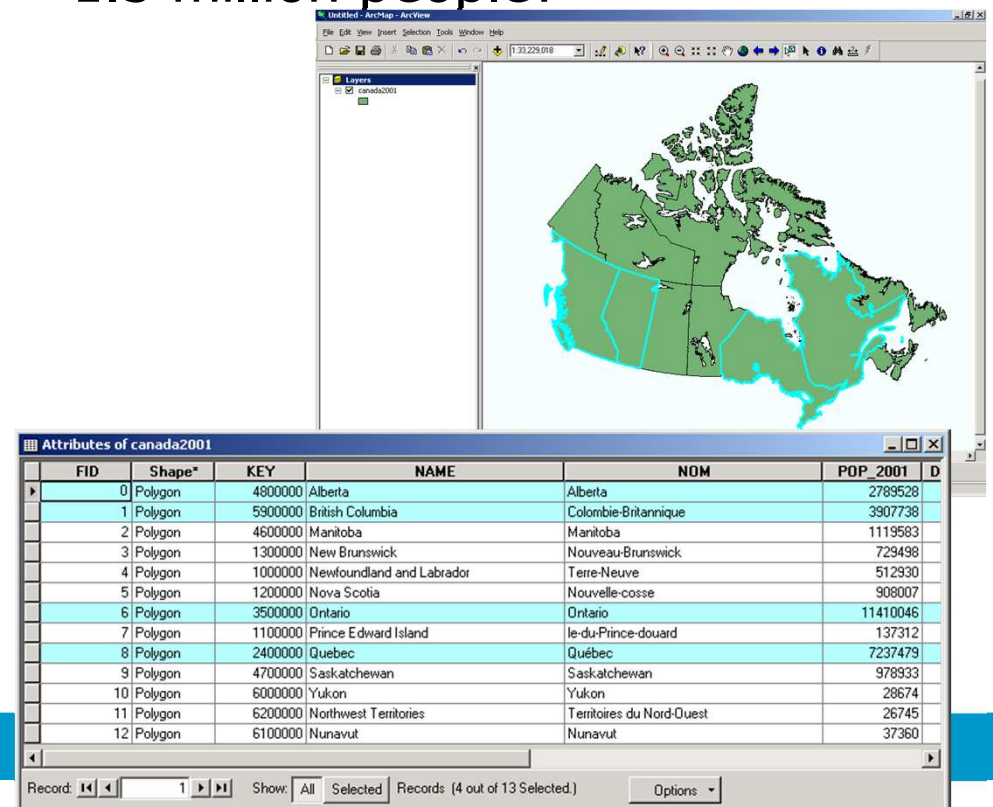
## Spatial Questions:

What provinces border Saskatchewan?



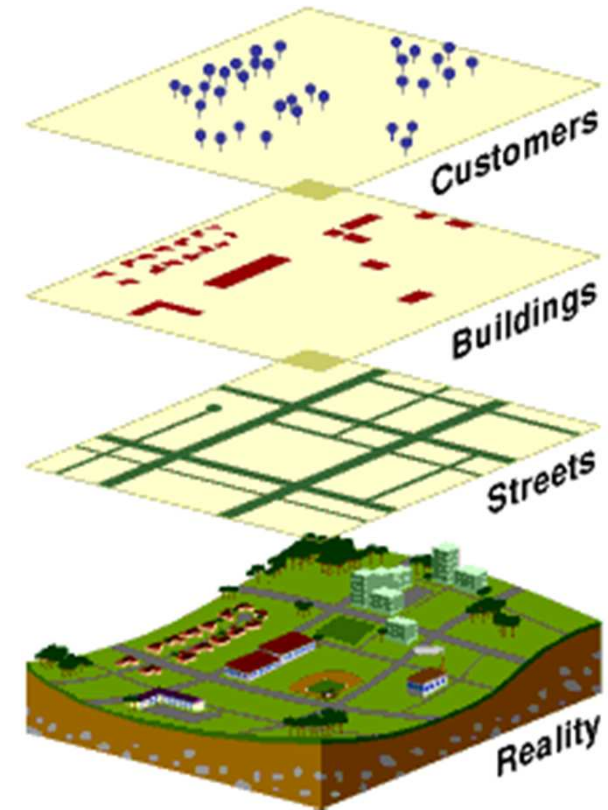
## Attribute Questions:

What provinces have more than 1.5 million people?



# What is a GIS?

- In a GIS, different types of information are represented as separate map layers
- Each layer is linked to descriptive information
- Layers are combined to make a map

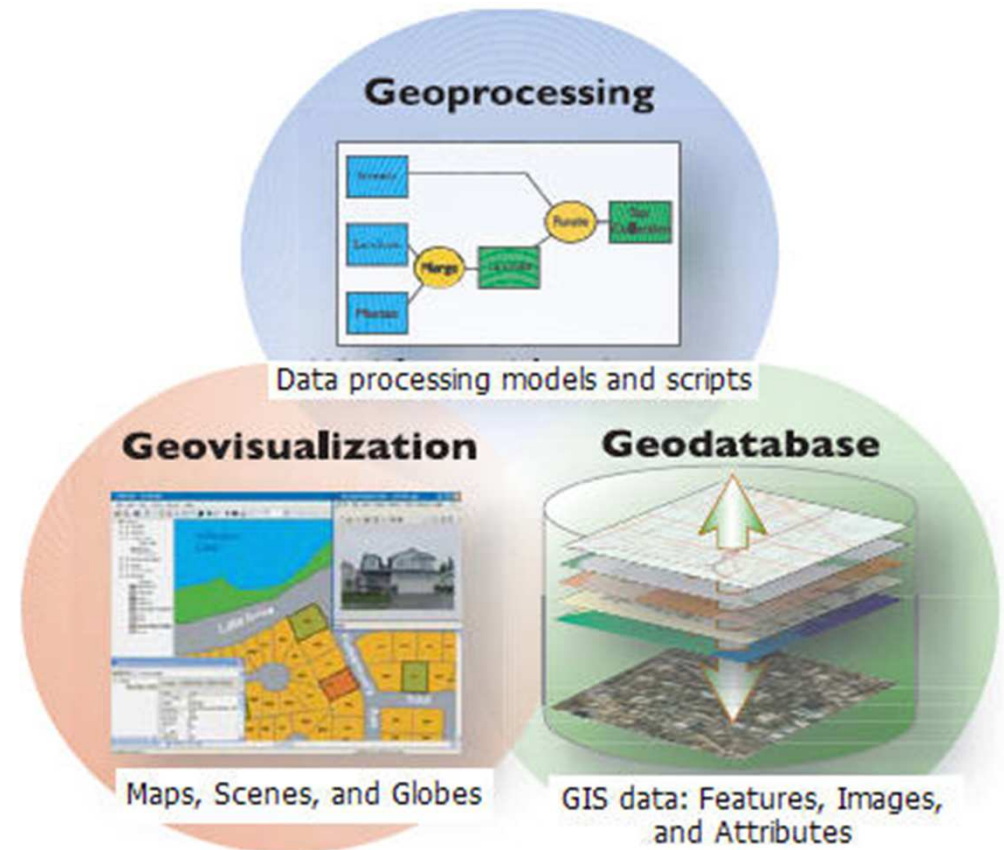




# Geographical Information Systems

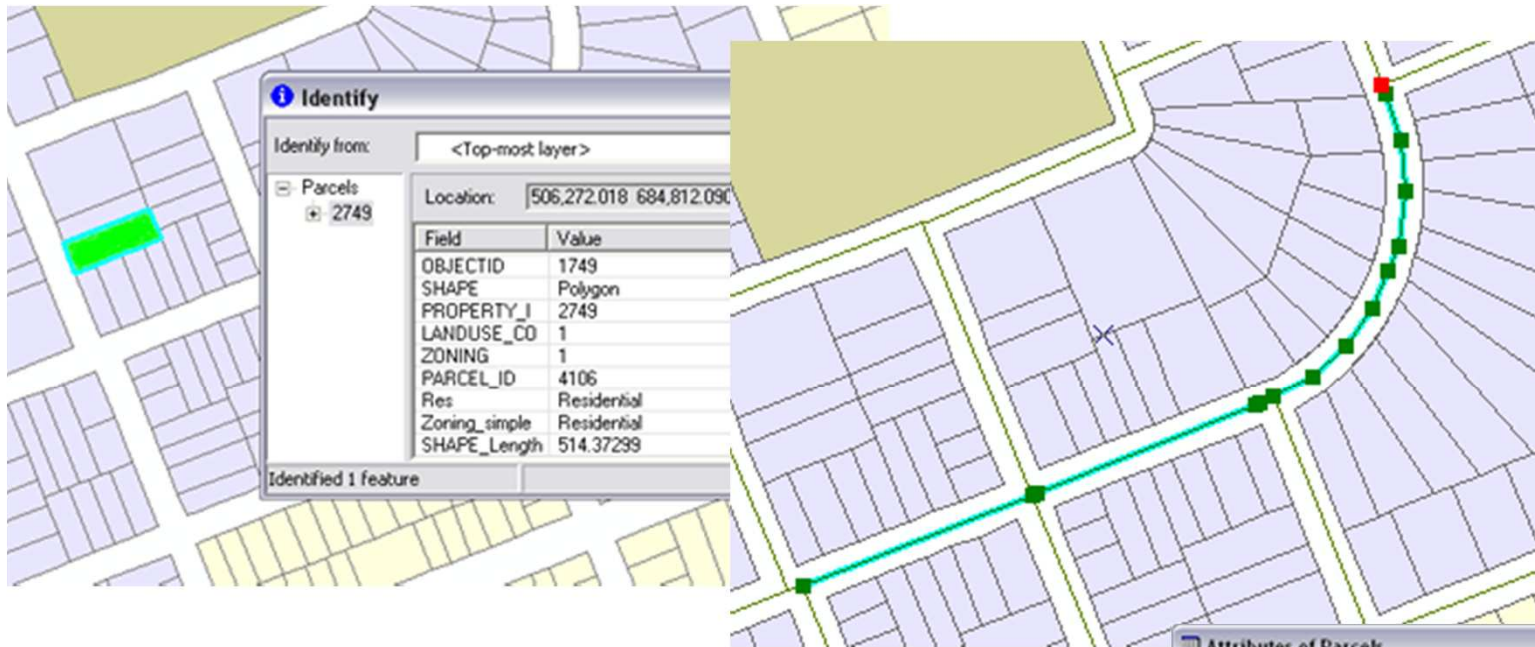
## Key functions of a GIS:

- Data management
- Mapping and Visualization
- Geoprocessing



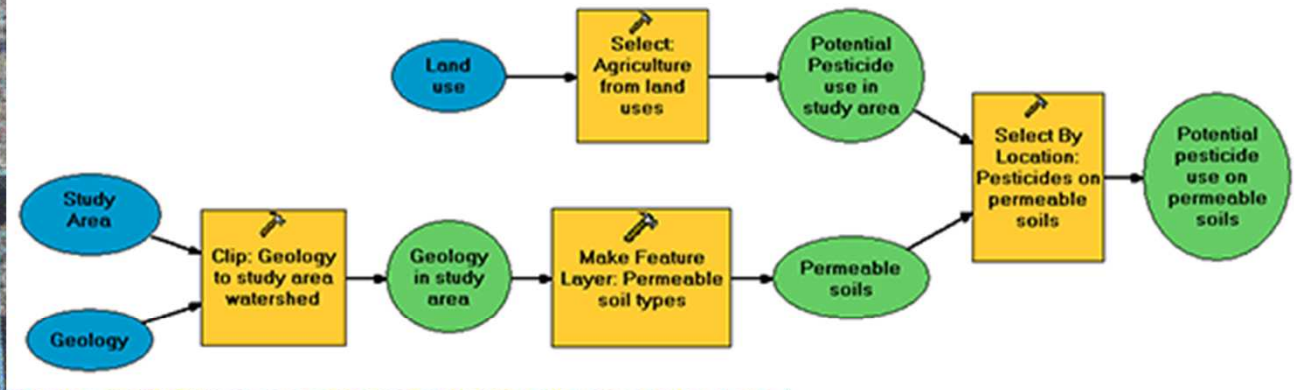
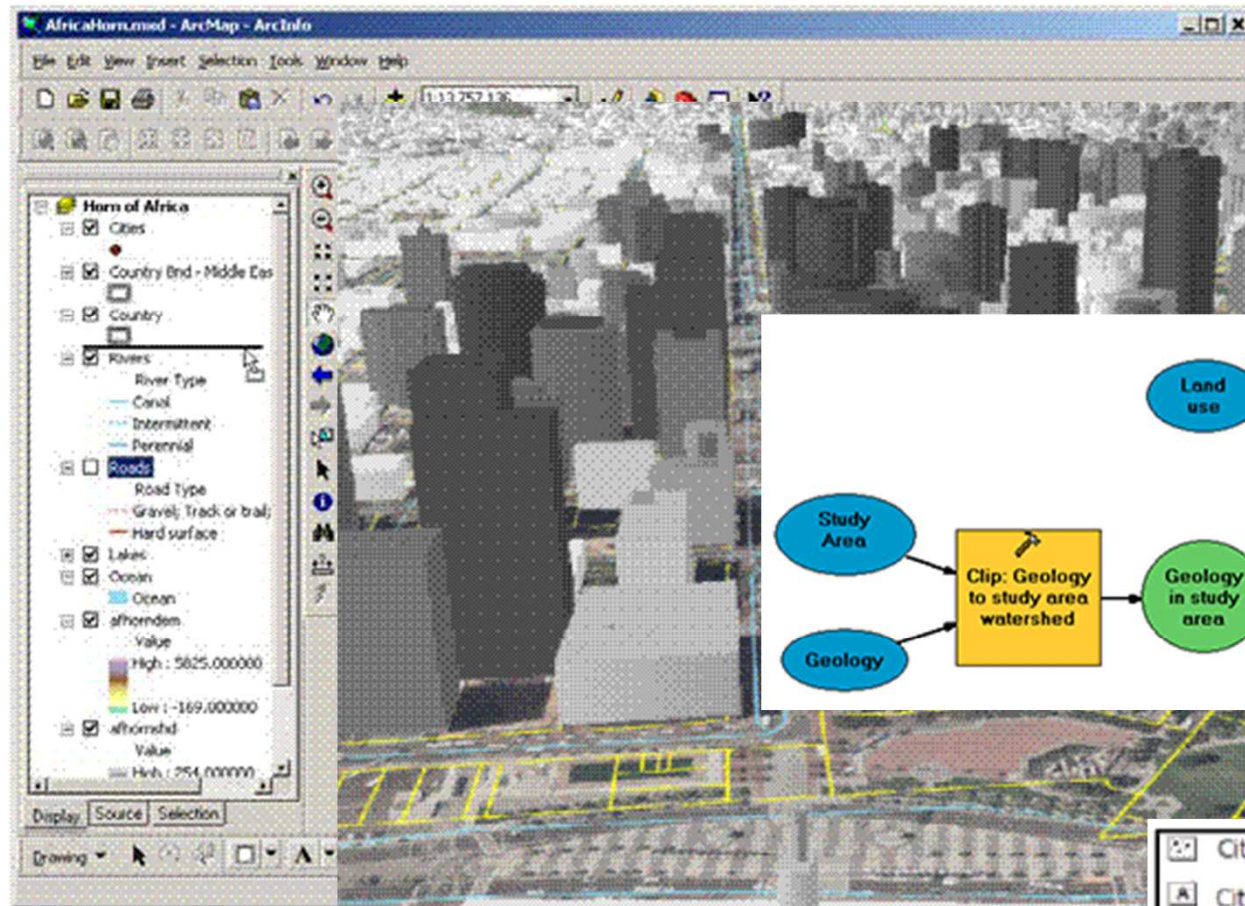


# Working with individual data elements



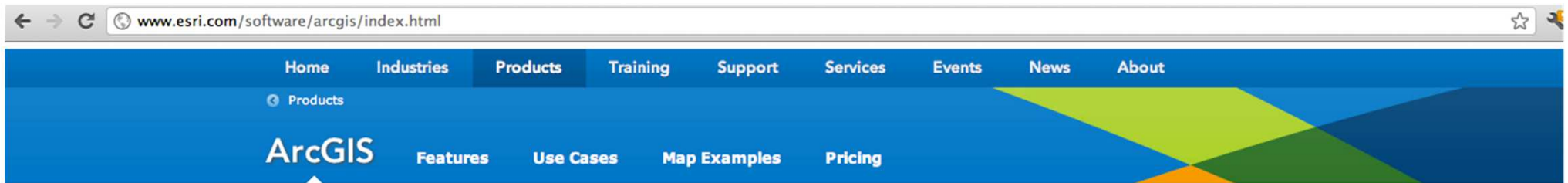
OBJECTID *	PROPERTY_ID *	PARCEL_ID	Res	Zoning_simple	SHAPE_Length
1537	2537	3894	Non-Residential	Commercial	326.211136
1538	2538	3895	Residential	Residential	367.422451
1539	2539	3896	Non-Residential	Commercial	298.362276
1540	2540	3897	Residential	Residential	401.268054
1541	2541	3898	Residential	Residential	400.160058
1542	2542	3899	Non-Residential	Commercial	291.521278
1543	2543	3900	Residential	Residential	373.737401
1545	2545	3902	Non-Residential	Commercial	329.564076
1546	2546	3903	Residential	Residential	503.8167
1547	2547	3904	Non-Residential	Commercial	419.270037
1548	2548	3905	Non-Residential	Commercial	754.51978
1549	2549	3906	Non-Residential	Commercial	312.336089

# Working with GIS datasets



Cities	Feature Class	Thu 9/23/2004 3:54 PM
CitiesAnno	Feature Class	Thu 9/23/2004 11:06 AM
Roads	Feature Class	Mon 10/4/2004 10:55 AM
RoadsAnno	Feature Class	Thu 9/30/2004 8:58 AM
ParkBoundaries	Feature Class	Tue 9/28/2004 8:56 AM
States	Feature Class	Thu 9/23/2004 3:54 PM
Streams	Feature Class	Thu 9/23/2004 11:06 AM
UtahRelief	Raster Dataset	Mon 10/4/2004 10:55 AM
150mNaturalColor	Raster Dataset	Thu 9/30/2004 8:58 AM

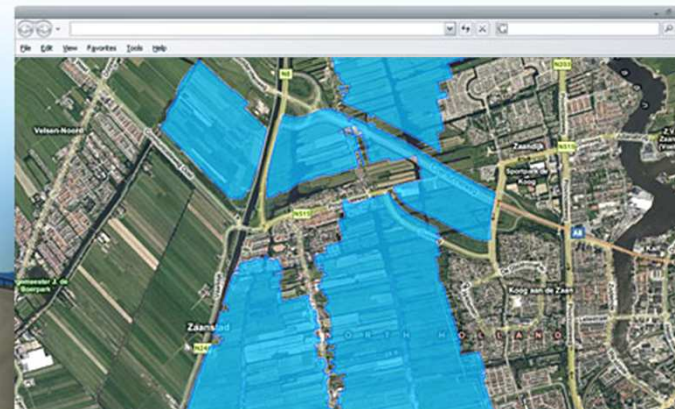




## Mapping & Analysis for Understanding Our World

A complete system for designing and managing solutions through the application of geographic knowledge.

[Discover How](#)



### How Organizations Use ArcGIS

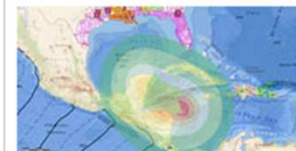
Learn more about ArcGIS [use cases](#)



Planning and Analysis



Asset/Data Management




Operational Awareness



Field Workforce

# GRASS GIS



## Welcome to GRASS GIS

You are at a GRASS mirror site in ITALY (IT) (other [mirror sites](#))  
This site is updated daily: 19 Apr 2012

[Intro](#) | [Docs](#) | [Download](#) | [Community](#) | [Applications](#) | [Development](#) | [Sponsors](#)

[Advanced search](#)

[About GRASS](#)

[Screenshots](#)

[Download](#)

[Wiki - help site](#) | [FAQ](#)

[Mirror sites](#)

[Mailing lists](#) | [IRC](#)

[Translating](#)

[Newsletter](#)

[Get involved!](#)

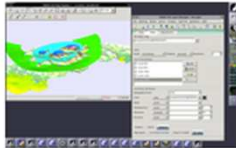
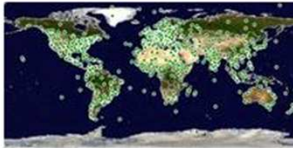
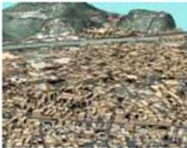
[GRASS in the Press](#)

[Bug/Feature trackers](#)

Donate

OPEN SOURCE GIS:  
A GRASS GIS  
Approach  
Third Edition

### Celebrating 28 years!



GRASS GIS User map

### Geographic Resources Analysis Support System

Commonly referred to as GRASS, this is free Geographic Information System (GIS) software used for geospatial data management and analysis, image processing, graphics/maps production, spatial modeling, and visualization. GRASS is currently used in academic and commercial settings around the world, as well as by many governmental agencies and environmental consulting companies. GRASS is an official project of the [Open Source Geospatial Foundation](#).

Module of the day:


[r.in.srtm](#) Import SRTM HGT files into GRASS

Latest News!

[XML](#) [RSS FEED](#)

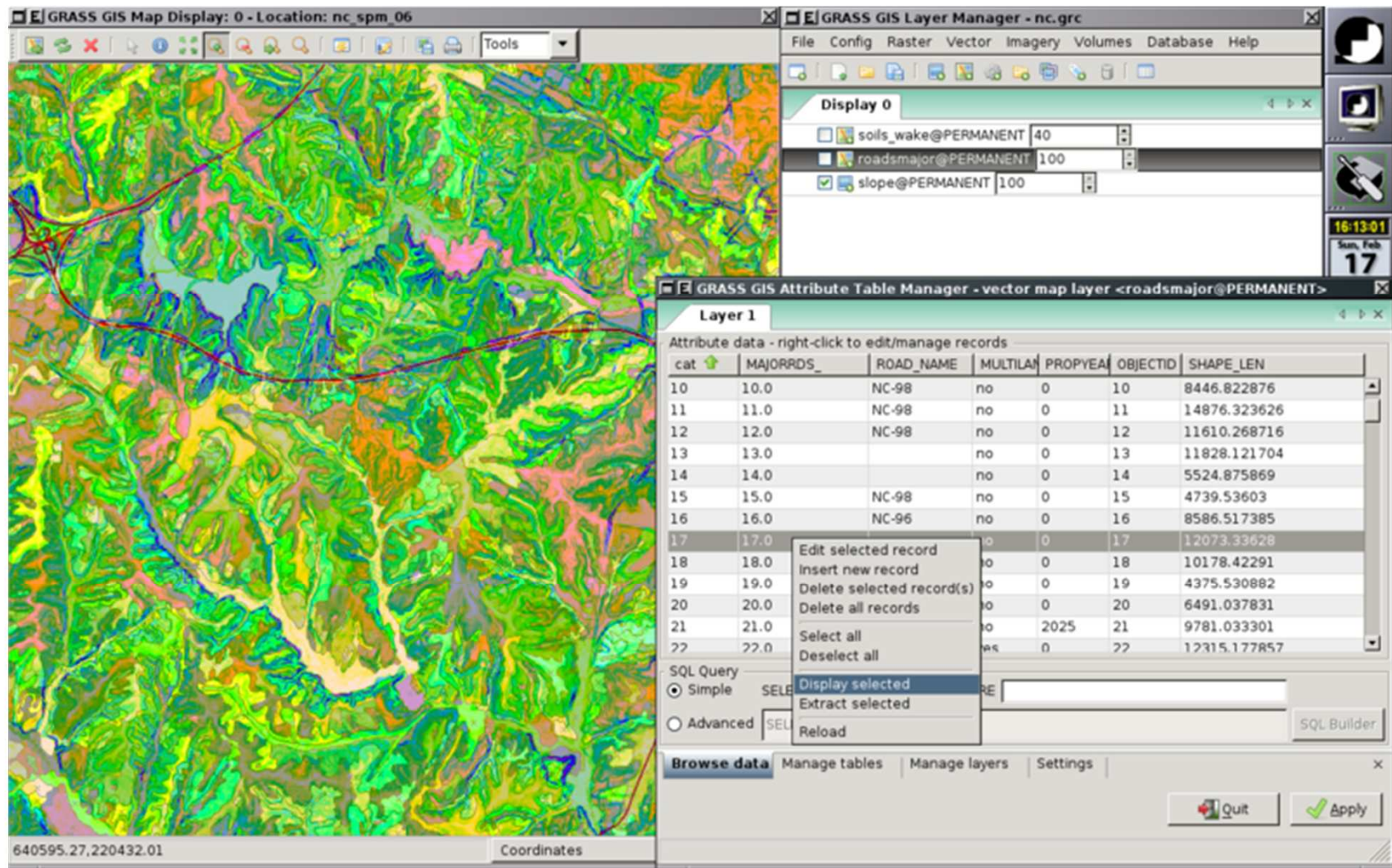
- 19 Feb 2012: [GRASS GIS 6.4.2 source code and selected binaries released](#) - New stable GRASS release version 6.4.2 with improvements and stability fixes
- 12 Jan 2012: [winGRASS 6.4.2RC3 and OSGeo4W-GRASS 6.4.2RC3 packages released](#) - New stable winGRASS pre-release version 6.4.2RC3 ready for download
- 12 Jan 2012: [GRASS 6.4.2RC3 source code released](#) - New stable GRASS pre-release version 6.4.2RC3 with stability fixes

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 **TU Delft**



# GRASS GIS



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# Quantum GIS



The screenshot shows the homepage of the Quantum GIS website. At the top, there is a navigation bar with links for Wiki, Planet, Chat, Bugs, Shop, Download, and Questions. A search bar and flags for English, German, and French are also present. The main banner features a medieval-style illustration of a city and the text "Quantum GIS Version 1.7.4 'Wrocław'". Below the banner, the "Main Menu" includes links to Home, About QGIS, Community, Documentation, Download, Commercial Support, Developer Meetings, User Meetings, Sponsorship, and Advanced Search. The "Upcoming Events" section lists "QGIS Hackfest, Lyon (April 12-15, 2012)", "FOSS4G-CEE, Prague (May 21 - 23, 2012)", and "GRASS Community Sprint, Prague (May 23 - 28, 2012)". The central content area welcomes visitors to the Quantum GIS Project, describes it as a user-friendly Open Source GIS licensed under the GNU GPL, and lists its supported operating systems and data formats. It also provides links to learn more about QGIS, including a user manual and a need help section. The "How to contribute" section mentions that Quantum GIS is a volunteer-driven project and provides information on how to contribute through code, documentation, or funding.

Quantum GIS

Search...

Wiki | Planet | Chat | Bugs | Shop | Download | Questions

The Quantum GIS project is pleased to **announce** the release of the QGIS version 1.7.4. Source code and binary packages are available from the **download page**.

**Quantum GIS**  
Version 1.7.4  
"Wrocław"

**Main Menu**

- » [Home](#)
- » [About QGIS](#)
- » [Community](#)
- » [Documentation](#)
- » [Download](#)
- » [Commercial Support](#)
- » [Developer Meetings](#)
- » [User Meetings](#)
- » [Sponsorship](#)
- » [Advanced Search](#)

**Upcoming Events**

- QGIS Hackfest, Lyon (April 12-15, 2012)
- FOSS4G-CEE, Prague (May 21 - 23, 2012)
- GRASS Community Sprint, Prague (May 23 - 28, 2012)

**Welcome to the Quantum GIS Project**

Quantum GIS (QGIS) is a user friendly Open Source Geographic Information System (GIS) licensed under the GNU General Public License. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, Unix, Mac OSX, and Windows and supports numerous vector, raster, and database formats and functionalities.

Our latest release is QGIS 1.7.4 you can read the release announcement [here](#)

**Learn more about QGIS**

Quantum GIS provides a continuously growing number of capabilities provided by core functions and plugins. You can visualize, manage, edit, analyse data, and compose printable maps. Get a first impression with some screenshots and a more detailed feature list.

**Want to learn even more?**

Check the latest User Guide or learn how you can customize QGIS to fit your needs with our API Documentation and PyQGIS Cookbook.

**How to contribute**

Quantum GIS is a volunteer driven project. We welcome contributions in the form of code contributions, bug fixes, bug reports, contributed documentation, advocacy and supporting other users on our mailing lists and [gis.stackexchange.com](#). If you are interested in actively supporting the project, you can find more information under the development menu and on the QGIS Wiki. We also welcome financial contributions in the form of sponsoring and funding.

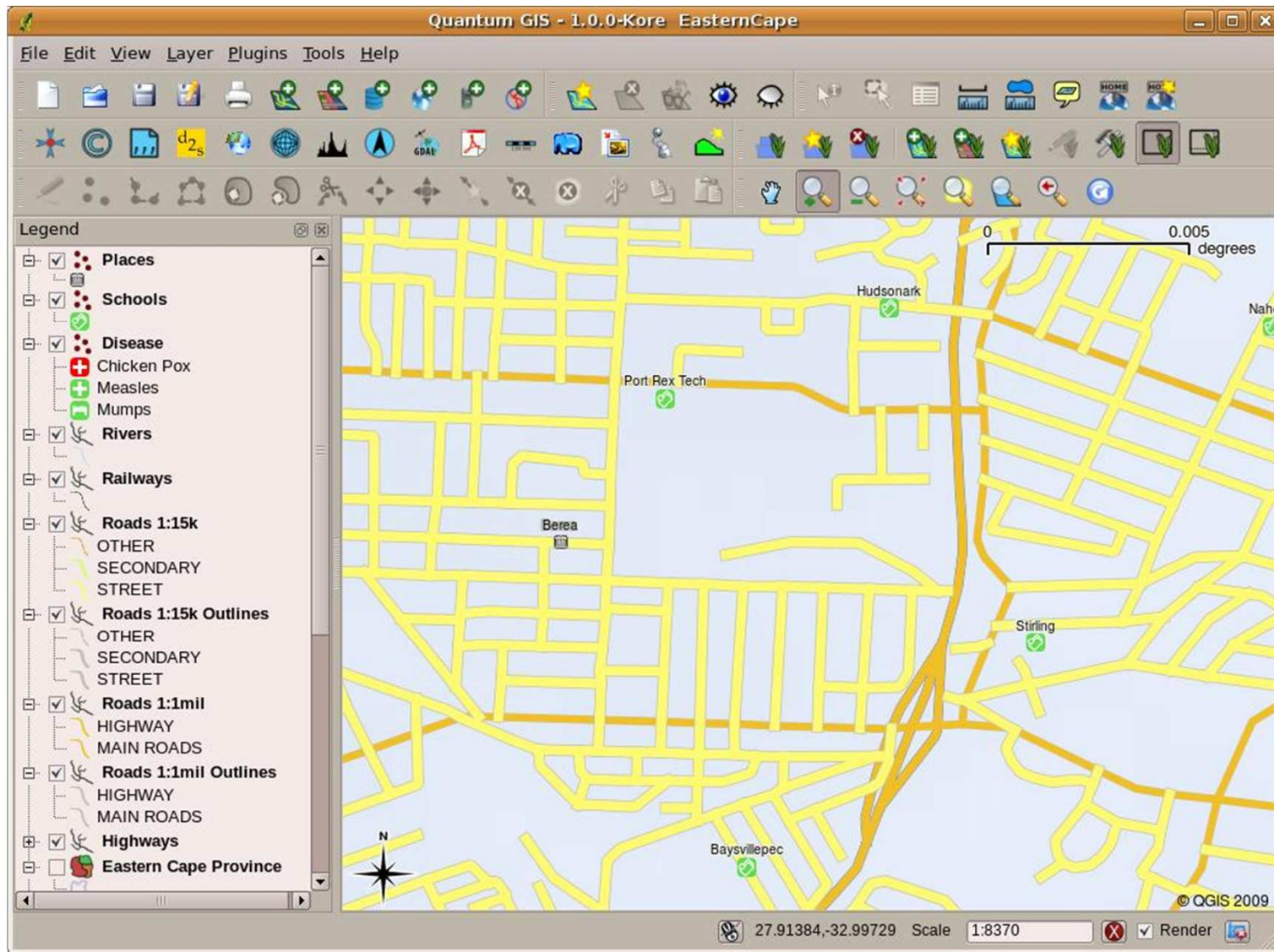
**Download Now Free!**

**Get the User Manual**

**Need help? Find it here!**



# Quantum GIS



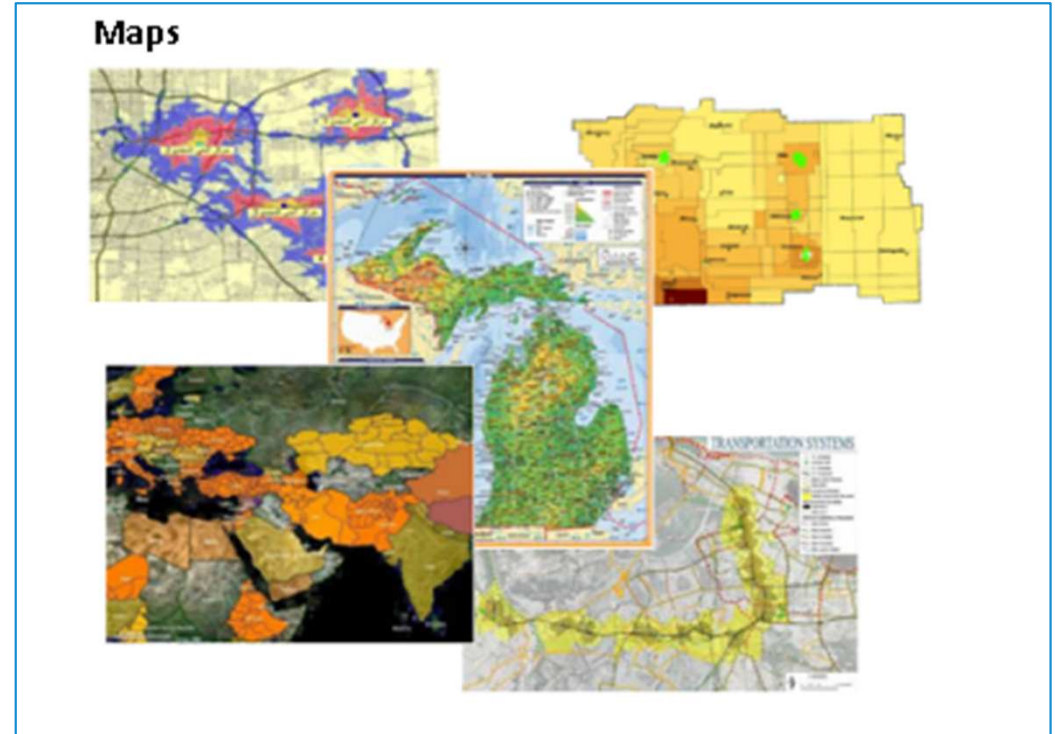
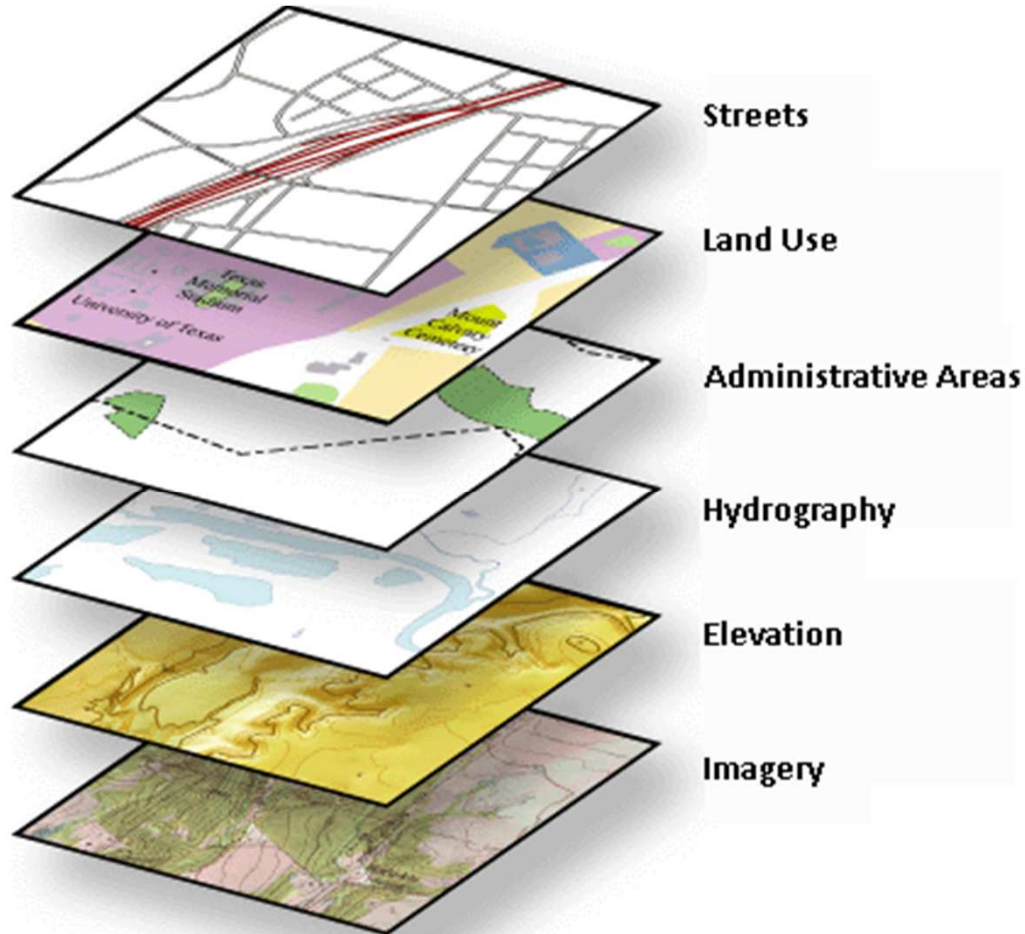
# CT5401 – Lecture 1

## Introduction to GIS

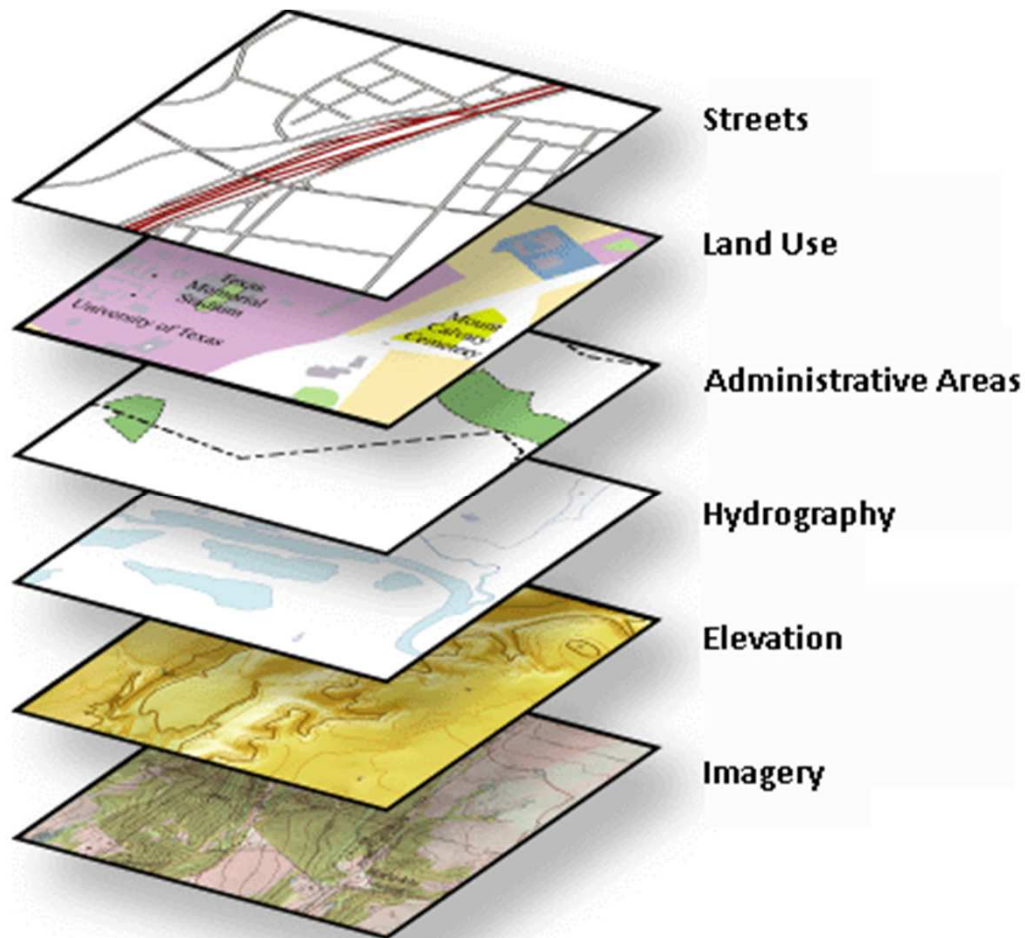
- What is GIS?
- **Data models to represent our world**
- Functions of a GIS
- Real applications of GIS in Hydrology and Water Resources Management
- Introduction to Assignment 1



# A map is made up of layers

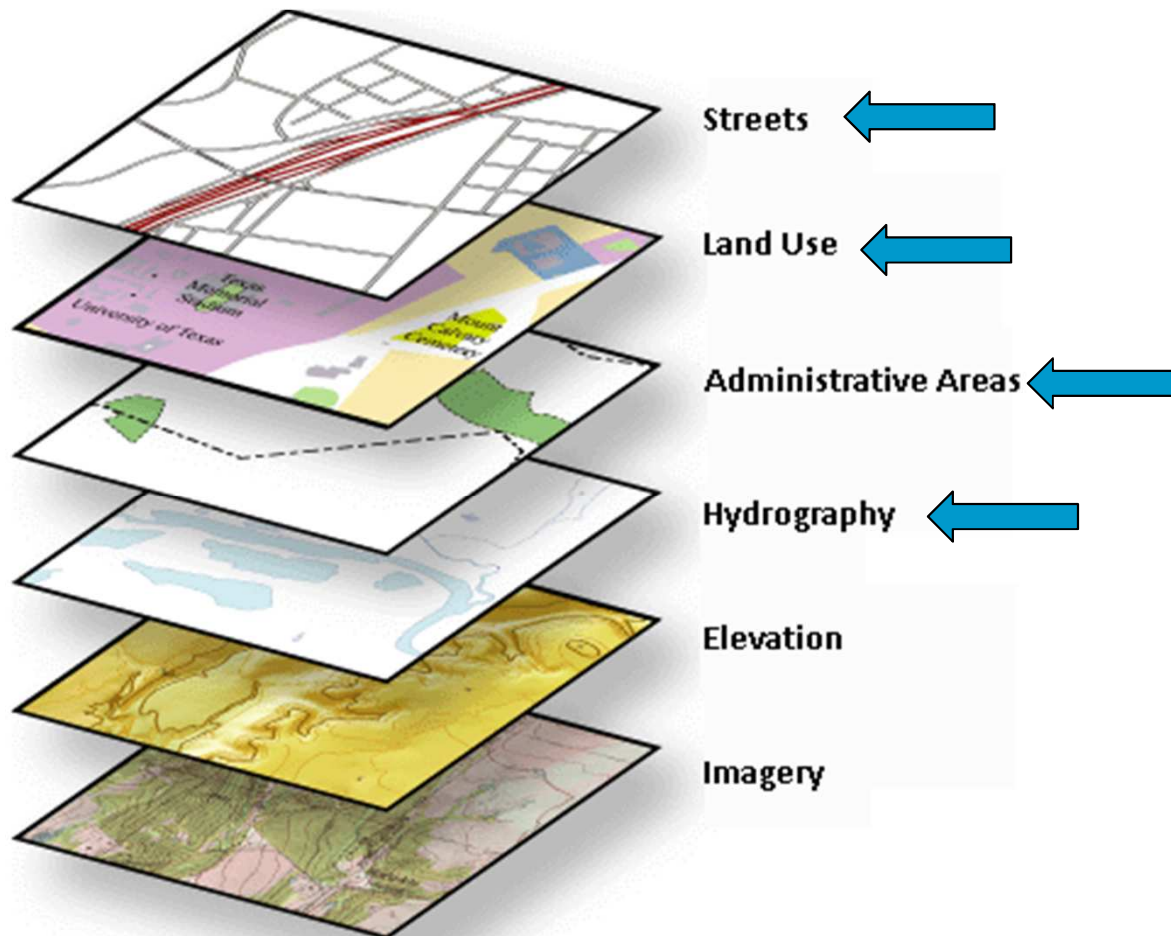


# GIS data structures



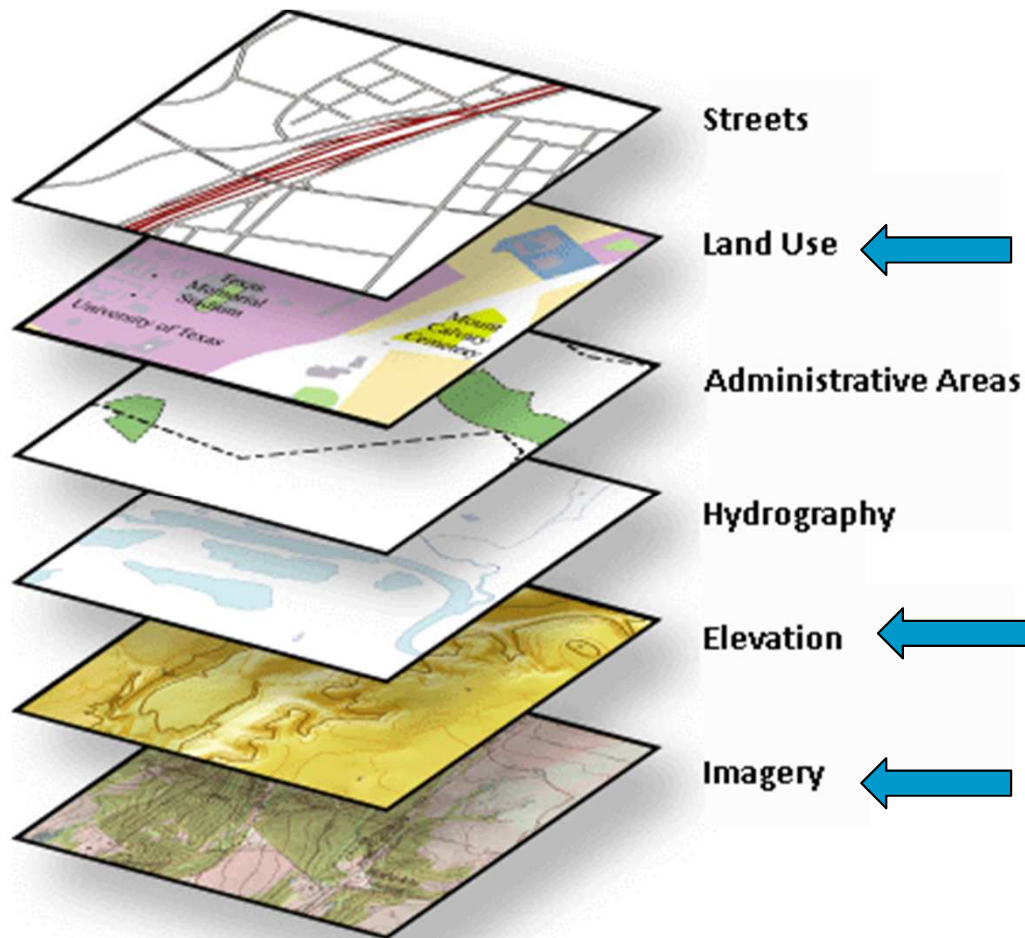
- Feature classes
- Raster datasets
- Attributes and descriptive information

# GIS data structures



- **Feature classes**
- Raster datasets
- Attributes and descriptive information

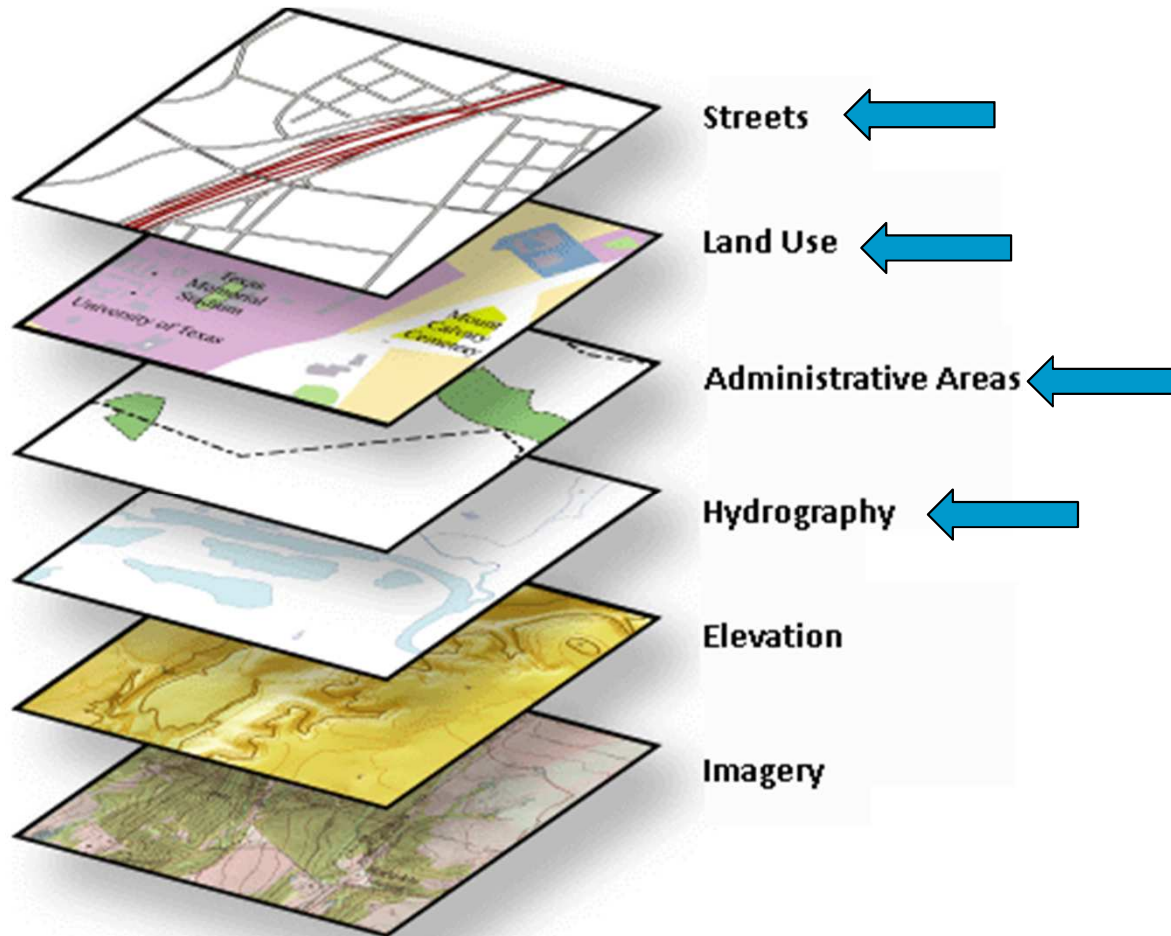
# GIS data structures



- Feature classes
- **Raster datasets**
- Attributes and descriptive information



# GIS data structures



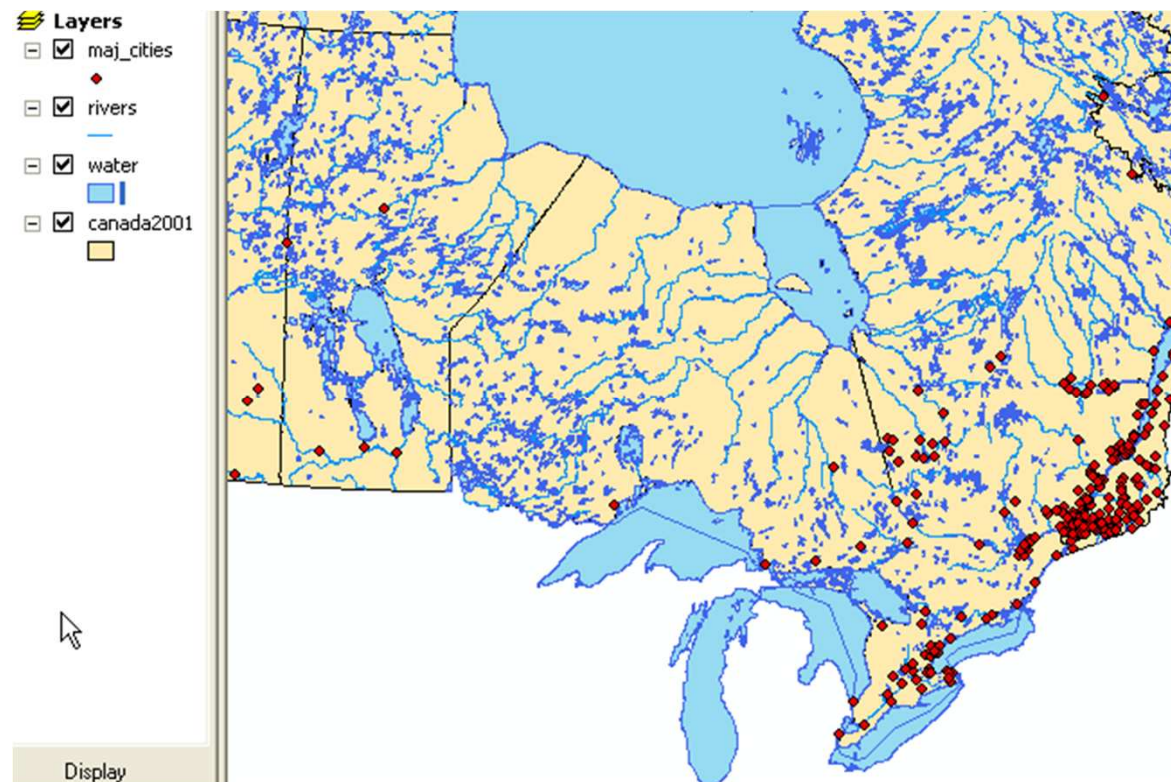
- Feature classes
- Raster datasets
- **Attributes and descriptive information**

# Vector for Discrete Data

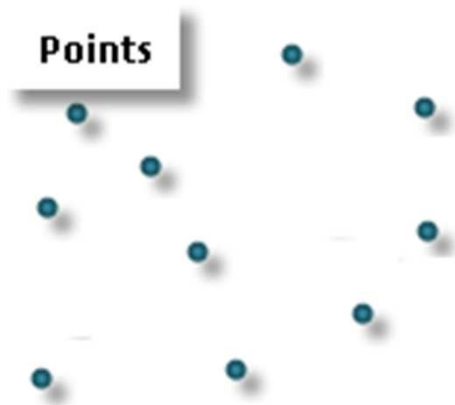
Vector is shape based data

A representation of the world using points, lines, and polygons

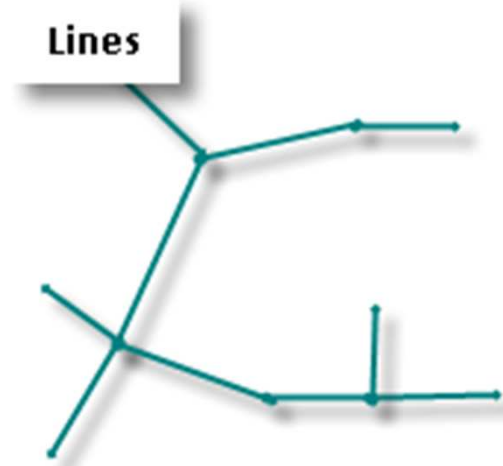
Vector models are useful for storing data that has distinct boundaries, such as country borders, land parcels and streets



# GIS data structures: Feature



e.g.  
Well locations  
Weather station locations  
Stream gauge locations  
Pollutant point sources  
Water hydrants  
Gulleys



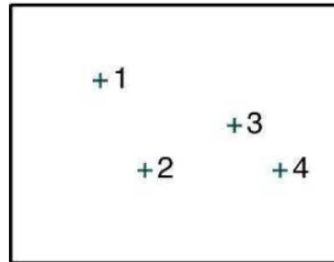
e.g.  
River  
Pipelines (e.g. water or sewer)  
Elevation contour lines  
Other contour lines (e.g. annual precipitation)  
Road centerline



e.g.  
Land parcel  
Soil types  
Land use zones  
Country boundaries  
Lakes  
Buildings

# Vector for Discrete Data

Points

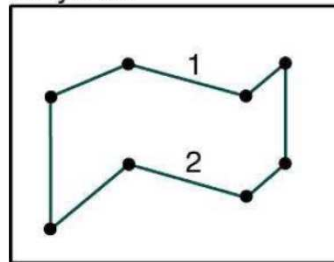


Point number

(x,y) coordinates

1	(2,4)
2	(3,2)
3	(5,3)
4	(6,2)

Polylines

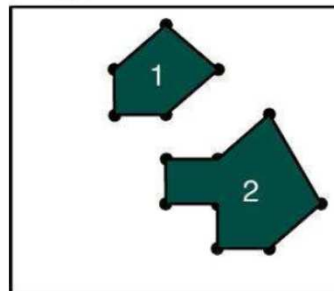


Polyline number

(x,y) coordinates

1	(1,5) (3,6) (6,5) (7,6)
2	(1,1) (3,3) (6,2) (7,3)

Polygons



Polygon number

(x,y) coordinates

1	(2,4) (2,5) (3,6) (4,5) (3,4) (2,4)
2	(3,2) (3,3) (4,3) (5,4) (6,2) (5,1) (4,1) (4,2) (3,2)



# Vector Dataset for Water Resources Management

## Grootschalige Basiskaart Nederland (GBKN)

A digital topographic map with prescribed content and precision including the most important topographic features (buildings, roads, waterways).

GBKN is a basemap, for all of the Netherlands, for use in many applications.

Scale from 1:500 to 1:5000.

# Grootschalige Basiskaart Nederland

## Applications:

**Consultancy**

**Presentation:** e.g. basis for maps

**Registration:** e.g. underground cables and pipes

**Design** e.g. civil engineering, architecture, infrastructure.

**Basis in GIS:** You can couple administrative data to geographical data on the built environment



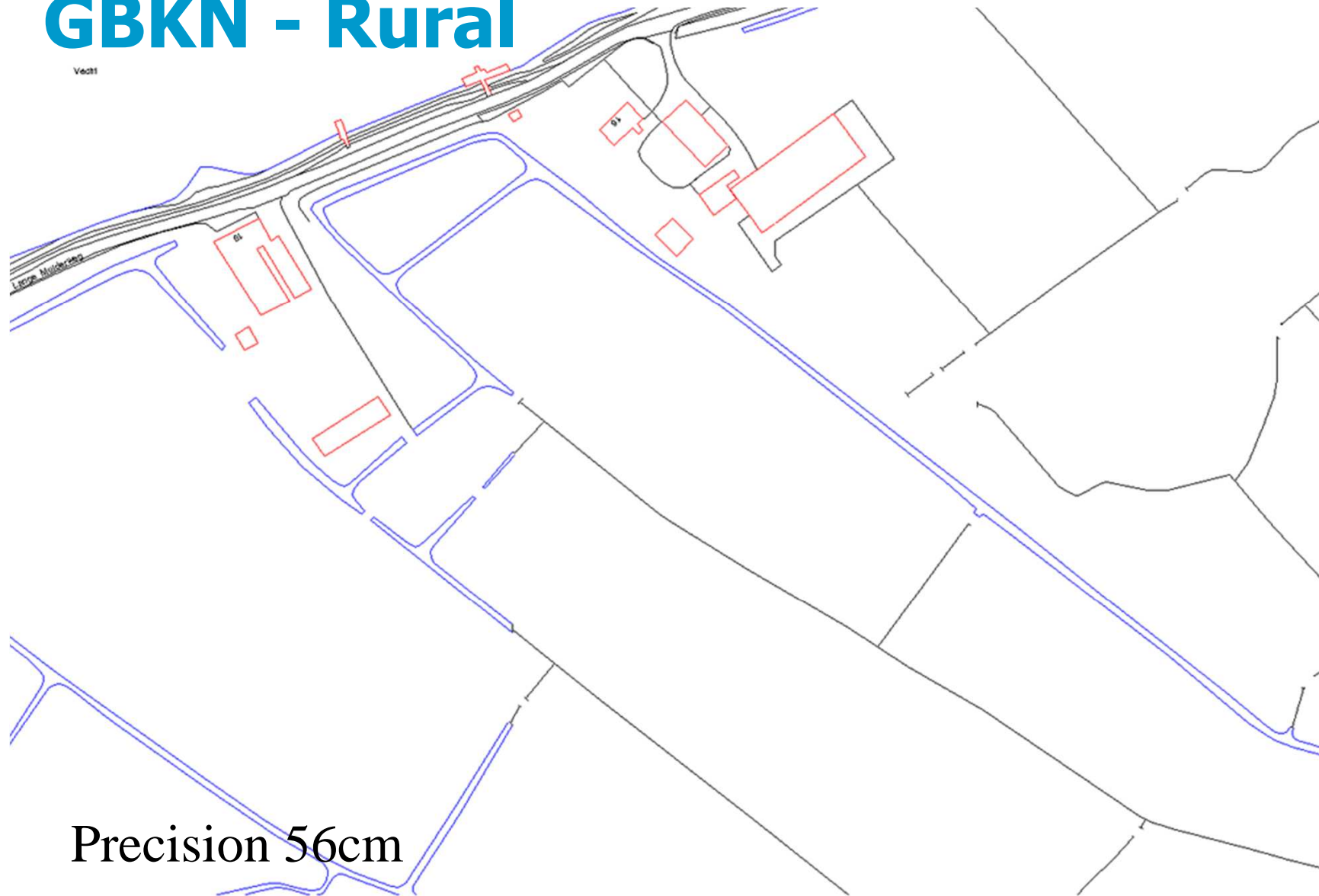
# Grootschalige Basiskaart Nederland

## GBKN- Urban



Precision 28cm

# GBKN - Rural



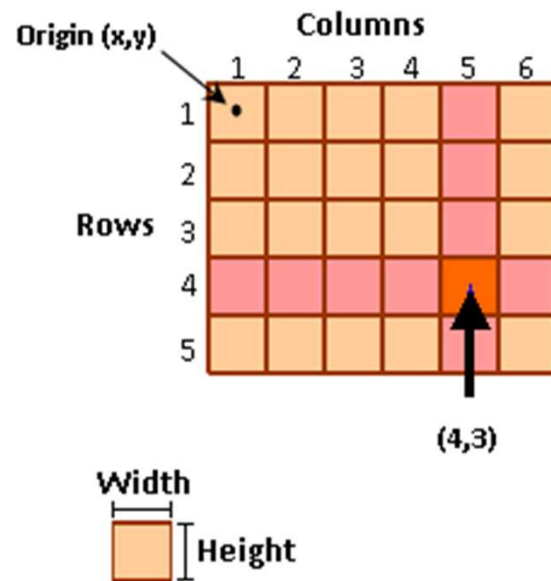


# GIS data structures: Raster

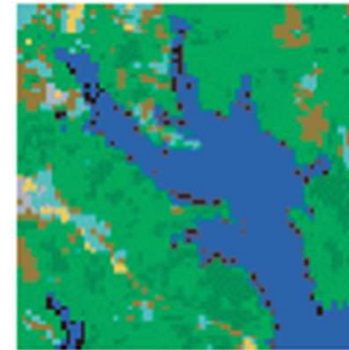
- Continuously changing values
- Stored as floating point values
- Elevation, noise pollution, rainfall, slope, temperature
- Cells organized in rows and columns, assigned index position number
- Many storage formats e.g. TIFF, JPEG, ESRI Grid



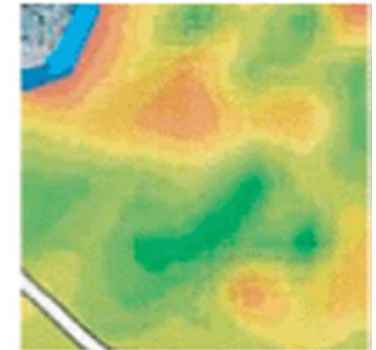
# GIS data structures: Raster



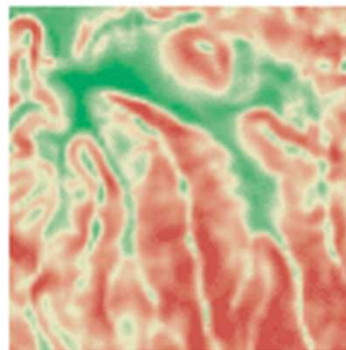
Orthophoto



Land Use



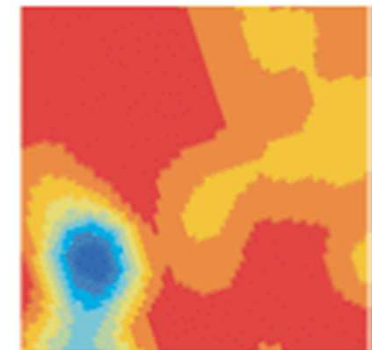
Concentration



Slope

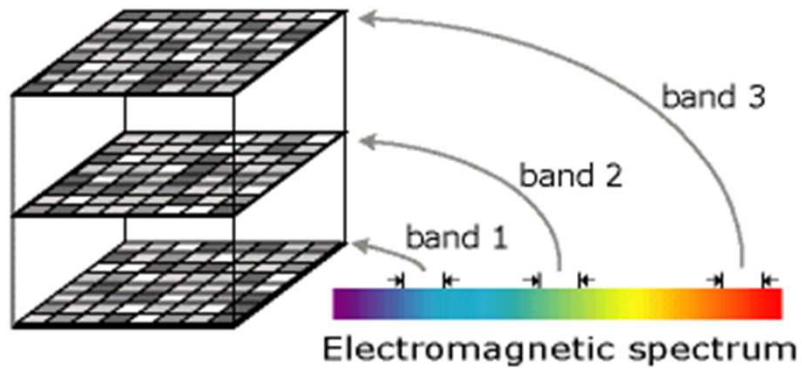


Elevation



Population

# GIS data structures: Raster



Landsat 7 images of Galveston, Texas before (left, 10/12/07) and after (right, 9/28/08), depicts scarring left after Hurricane Ike.

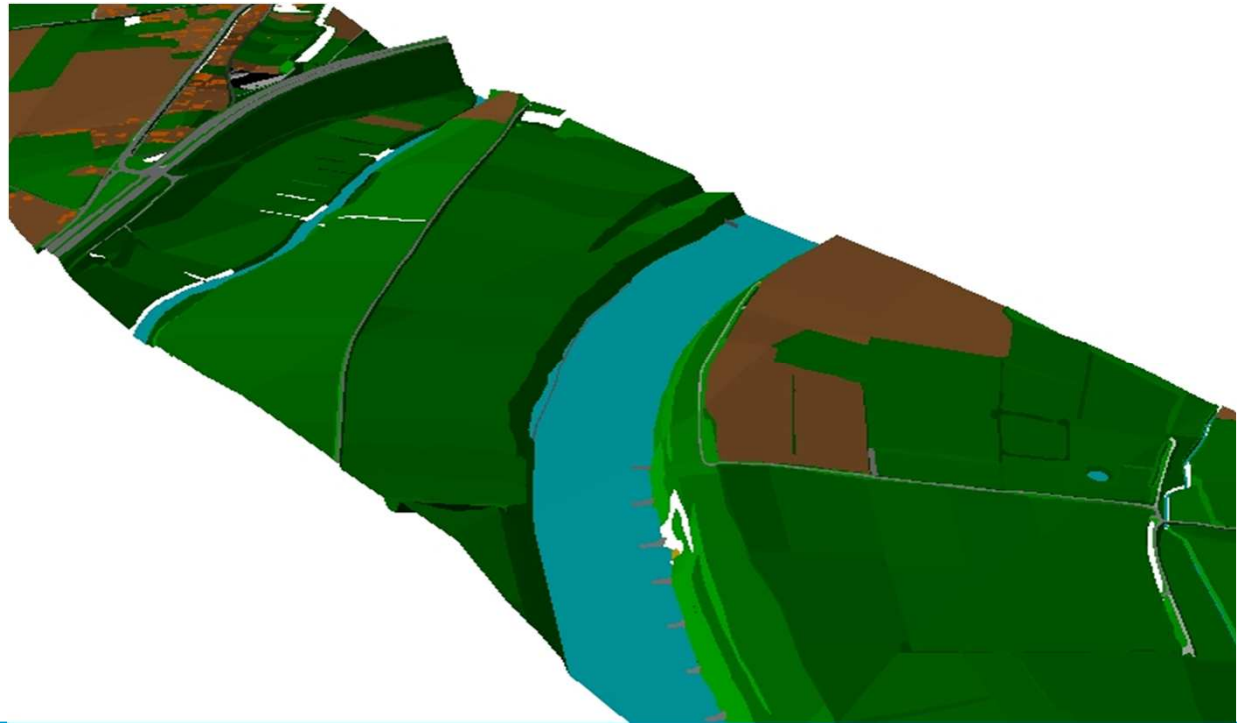


# Raster Dataset

## Digitaal Topografisch Bestand (DTB)

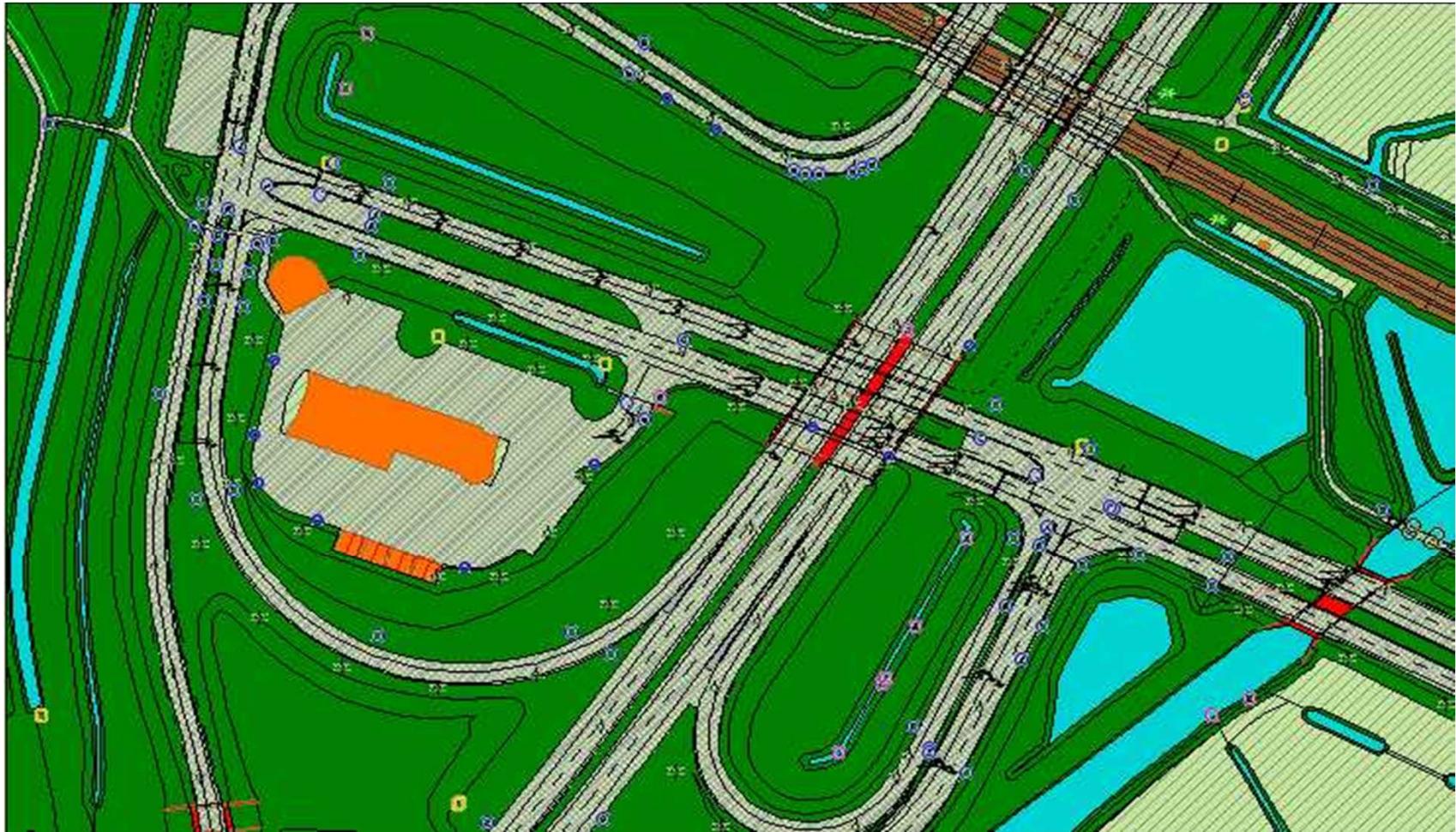
Produced by **Rijkswaterstaat** (Ministry for Infrastructure and Environment)

Detailed topographic geo-information (Scale 1:1000) on roads and waterways.





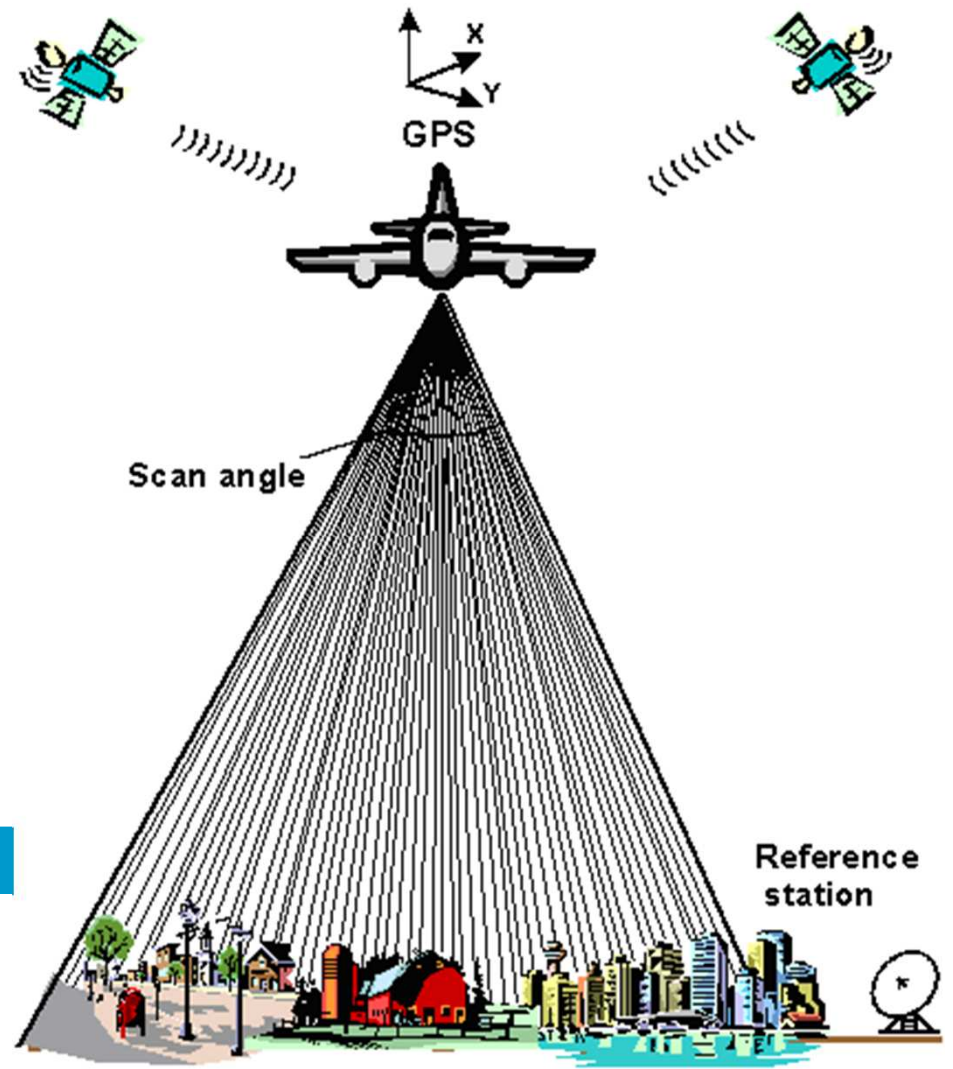
# Digitaal Topografisch Bestand (DTB)



# Actueel Hoogtebestand Nederland

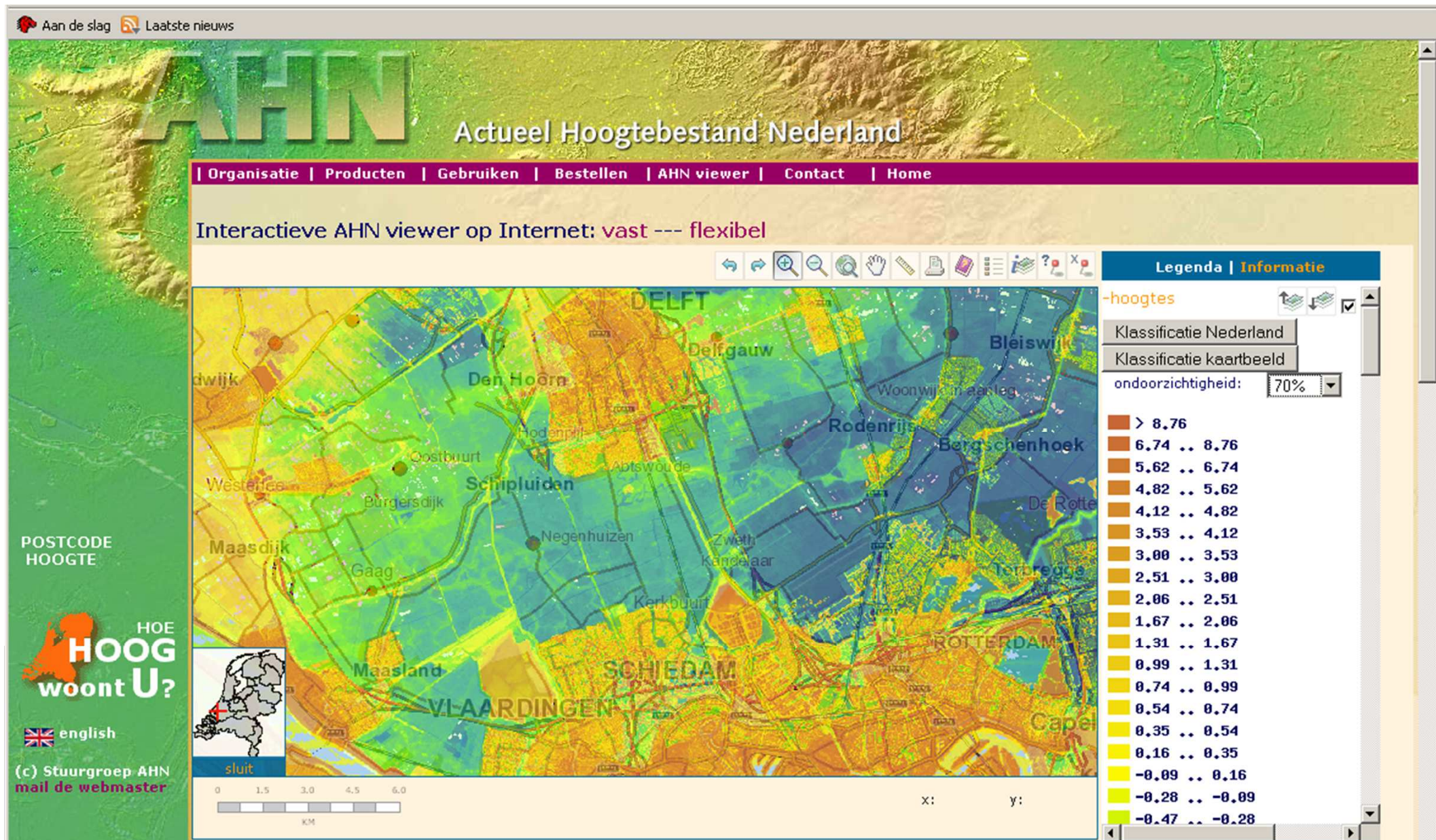
## Actual Height Model of the Netherlands

- Website: [www.ahn.nl](http://www.ahn.nl)
- Airborne Laser Altimetry
  - LIDAR
    - Light Detection and Ranging





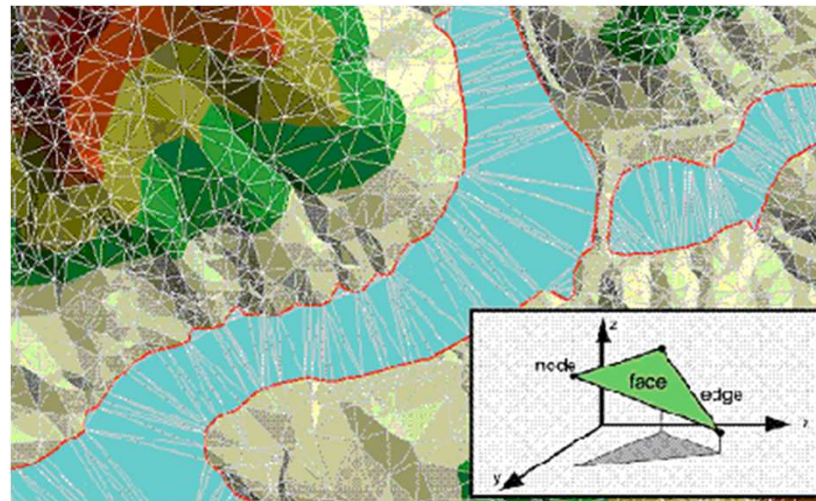
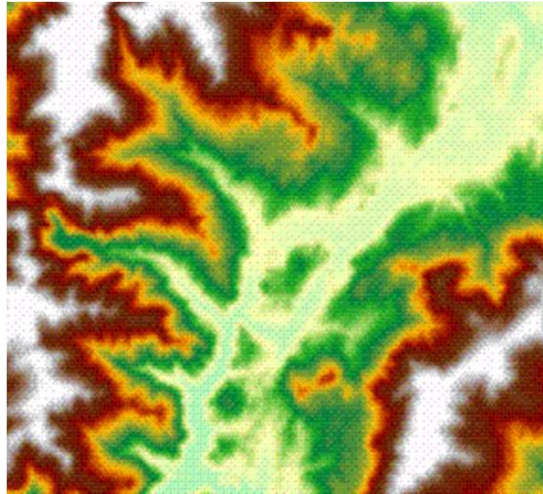
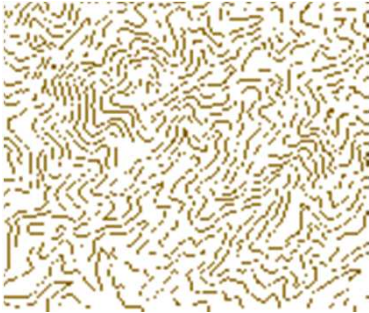
# www.ahn.nl/kaart



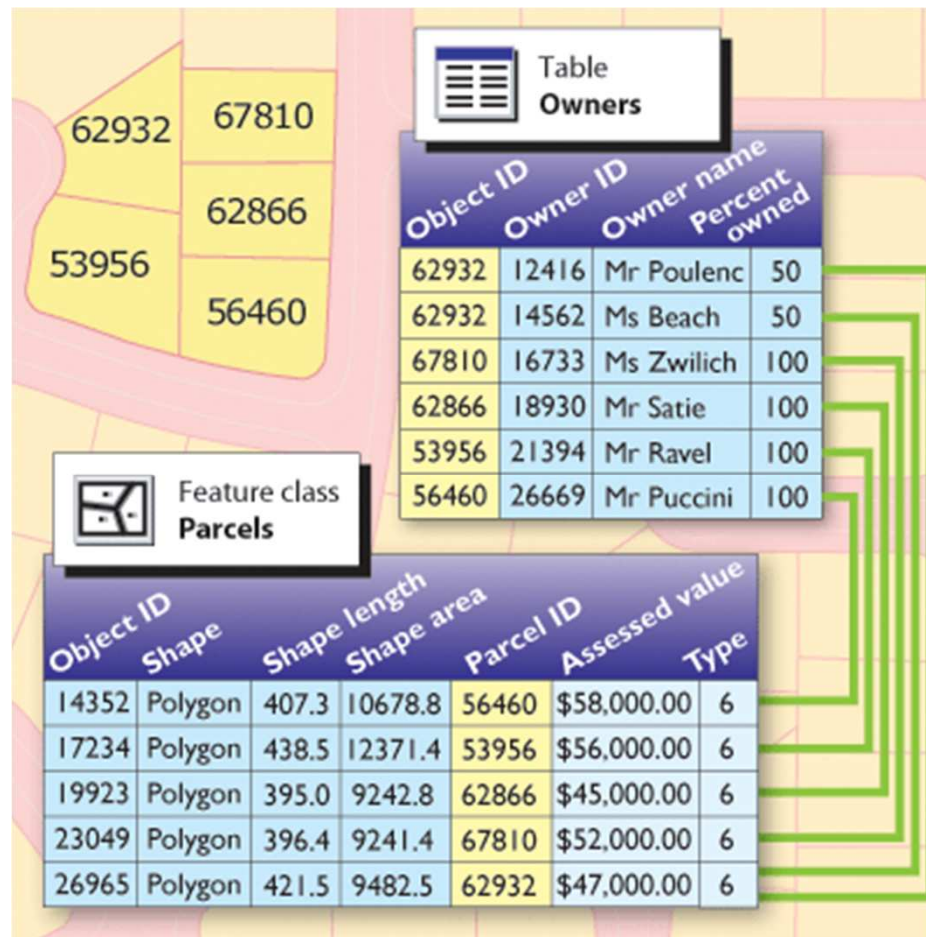


# Surfaces

can be represented using features or rasters



# GIS data structure: Attributes



# Activity: GIS data models for Water Resources Management

**Here are five tasks you might have as a water manager:**

- (a) Water supply demand and forecasting
- (b) Wastewater and stormwater system design
- (c) Flood damage assessment
- (d) Drought monitoring & warning
- (e) Designing a water quality monitoring network & database.

**Divide into groups of 4 students.**

**Each group will focus on one task.**



# Activity: GIS data models for Water Resources Management

**For your task:**

- 1) What data will you collect for your geodatabase?**
- 2) Will that data be raster/feature/attribute data?**
- 3) What will the attributes of the feature data be?**
- 4) Can you think of 3 spatial questions you might ask?  
3 attribute questions?**

3 minutes - Think by yourself and make a list

10 minutes – Combine your list with the rest of your group  
and brainstorm

15 minutes - Share results with whole class.  
Do they have any additional suggestions?

(Each group appoint someone to write notes, and someone to present to whole class)

# CT5401 – Lecture 1

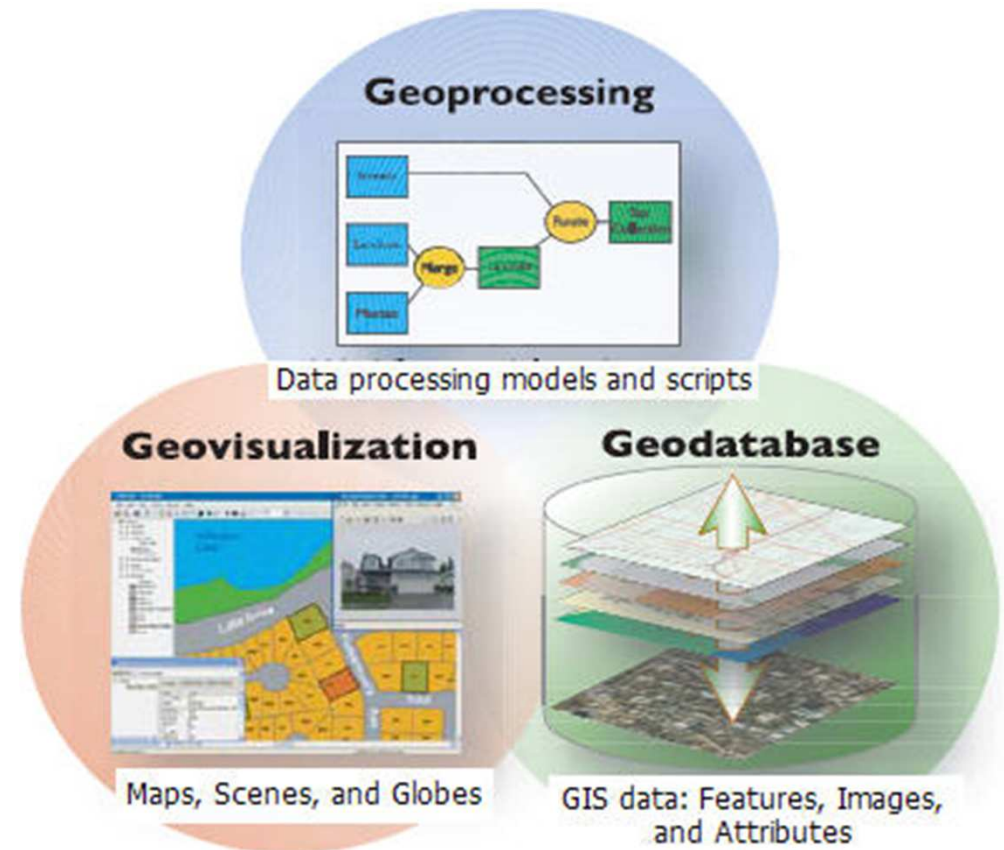
## Introduction to GIS

- What is GIS?
- Data models to represent our world
- **Functions of a GIS**
- Real applications of GIS in Hydrology and Water Resources Management
- Introduction to Assignment 1

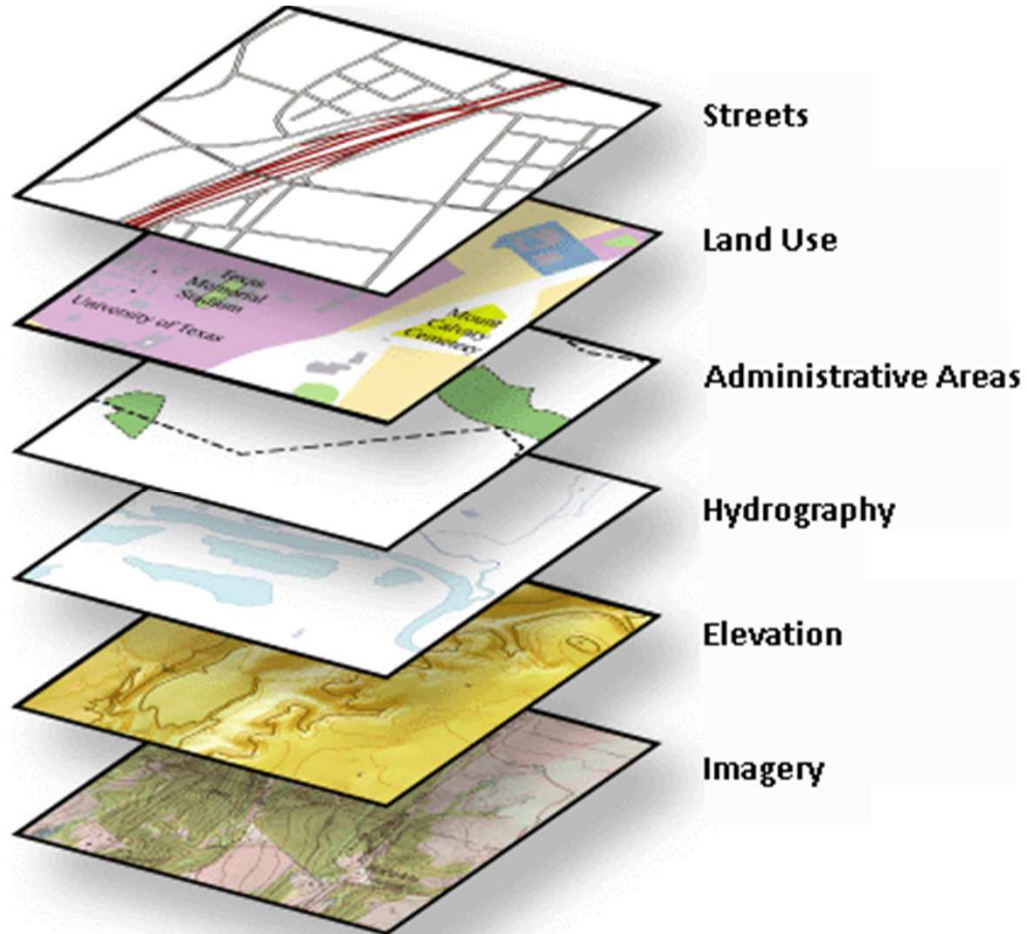
# Geographical Information Systems

## Key functions of a GIS:

- ***Data management***
- Mapping and Visualization
- Geoprocessing



# Data management

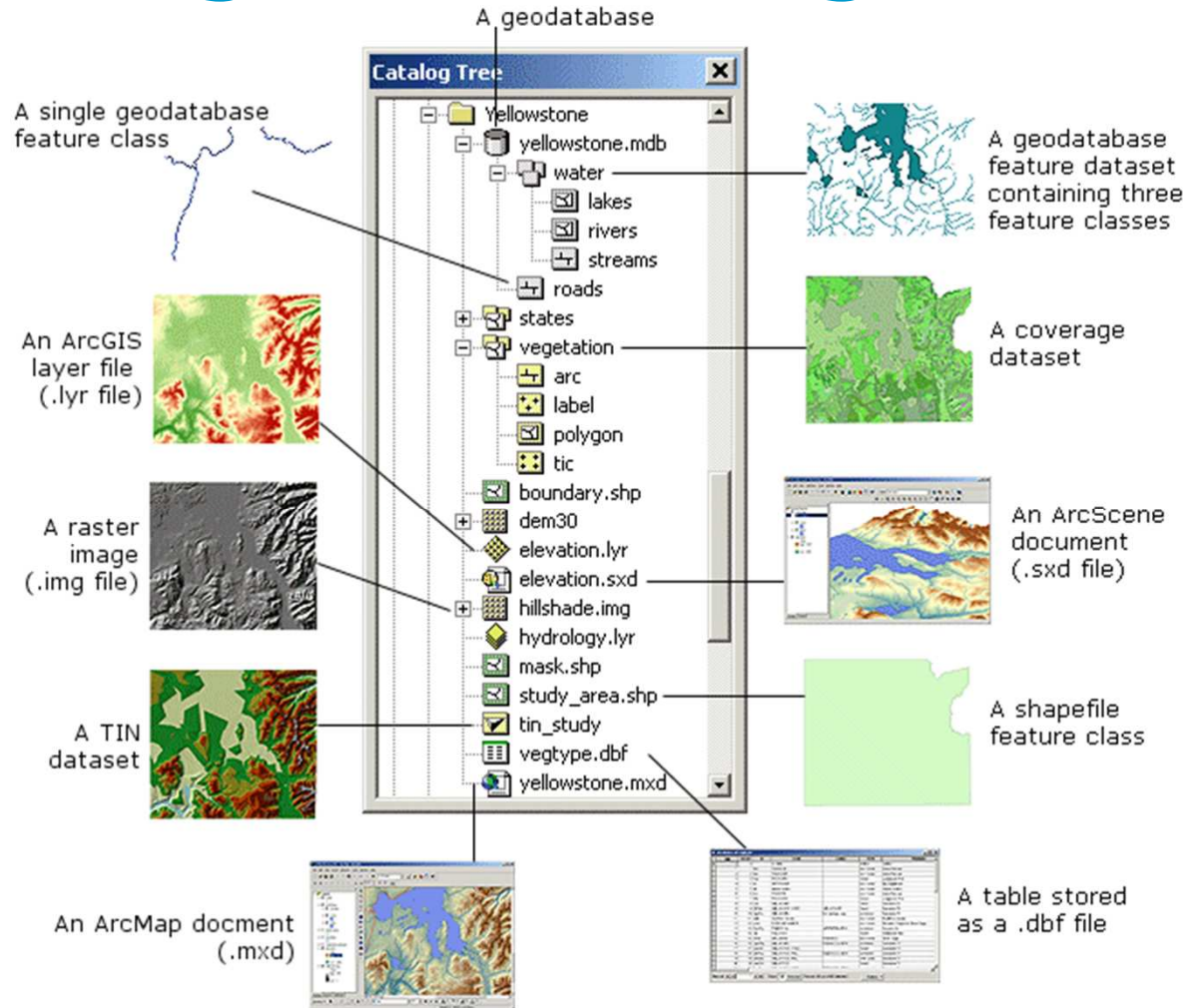


## Maps



# Data Management

## ArcCatalog: The Catalog Tree

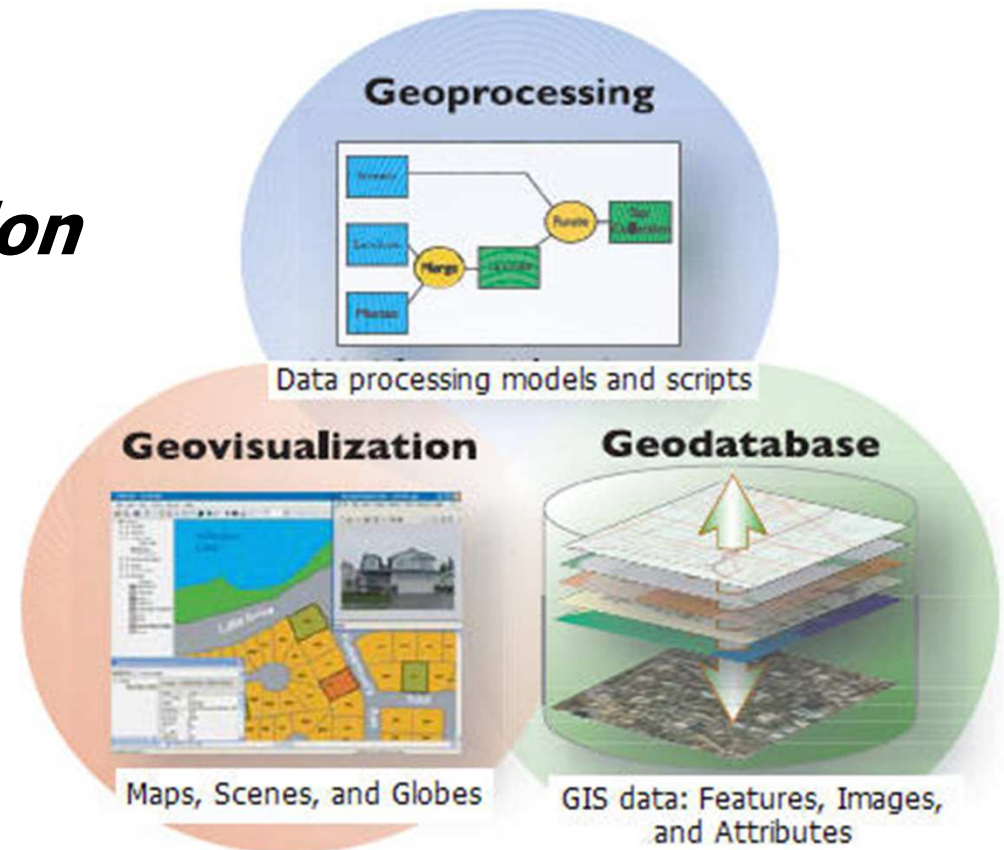




# Geographical Information Systems

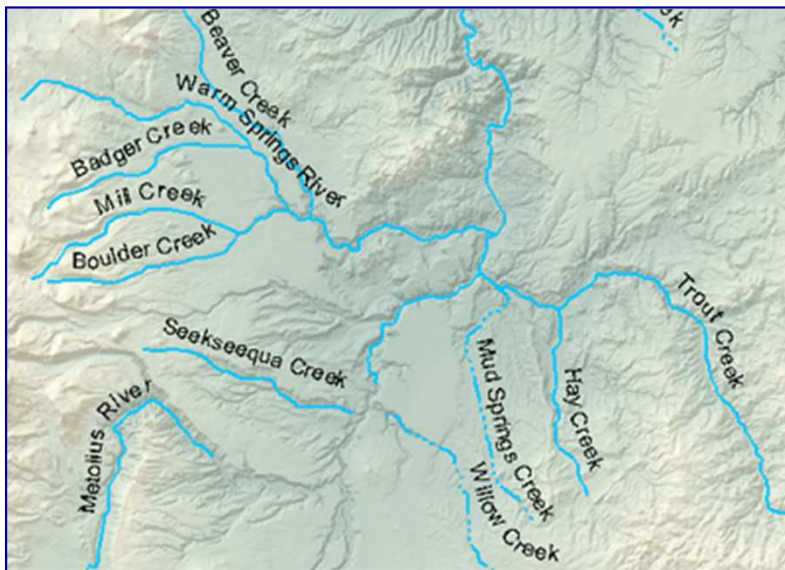
## Key functions of a GIS:

- Data management
- ***Mapping and Visualization***
- Geoprocessing

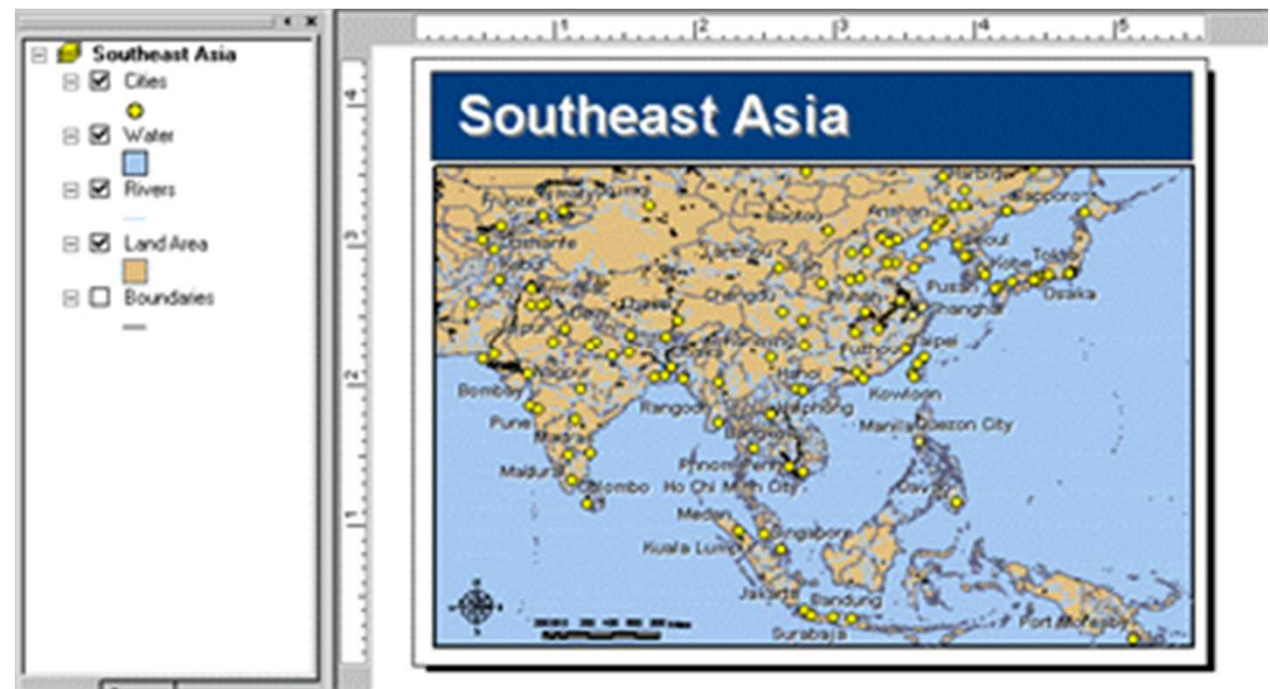




# Mapping and Visualization

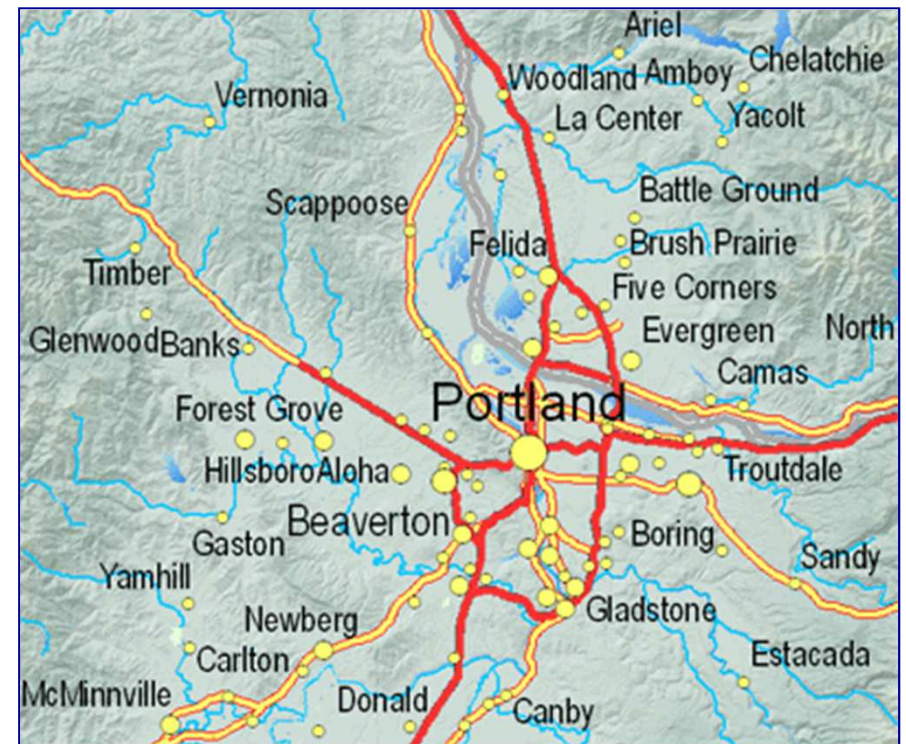
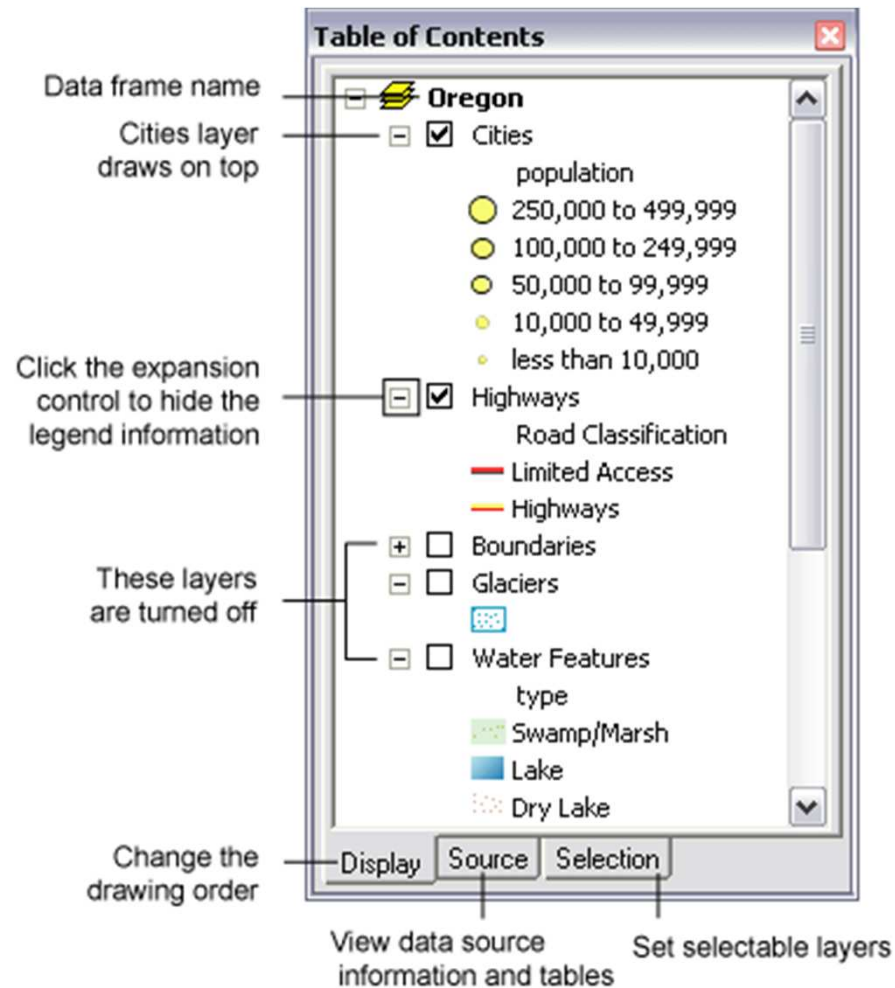


## Single symbol maps

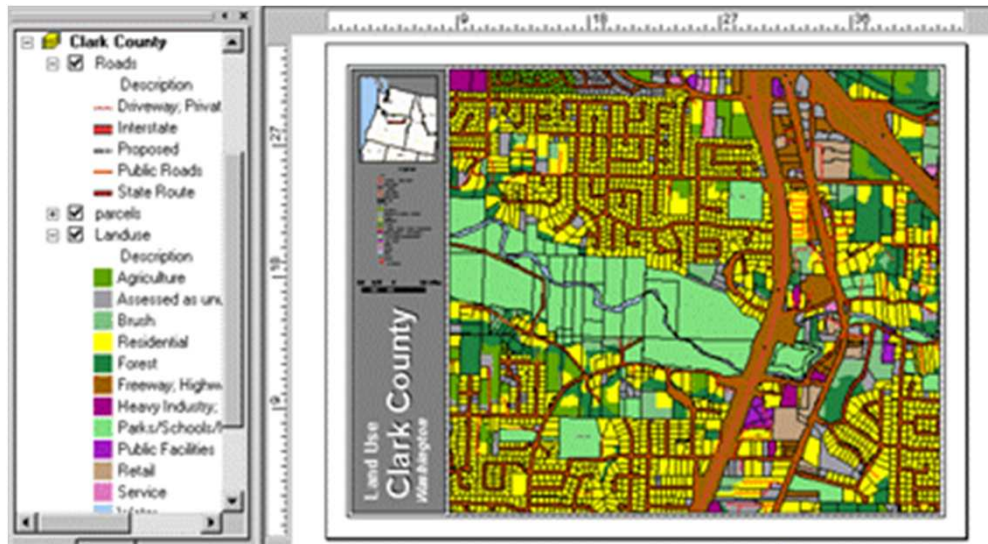


# Mapping and Visualization

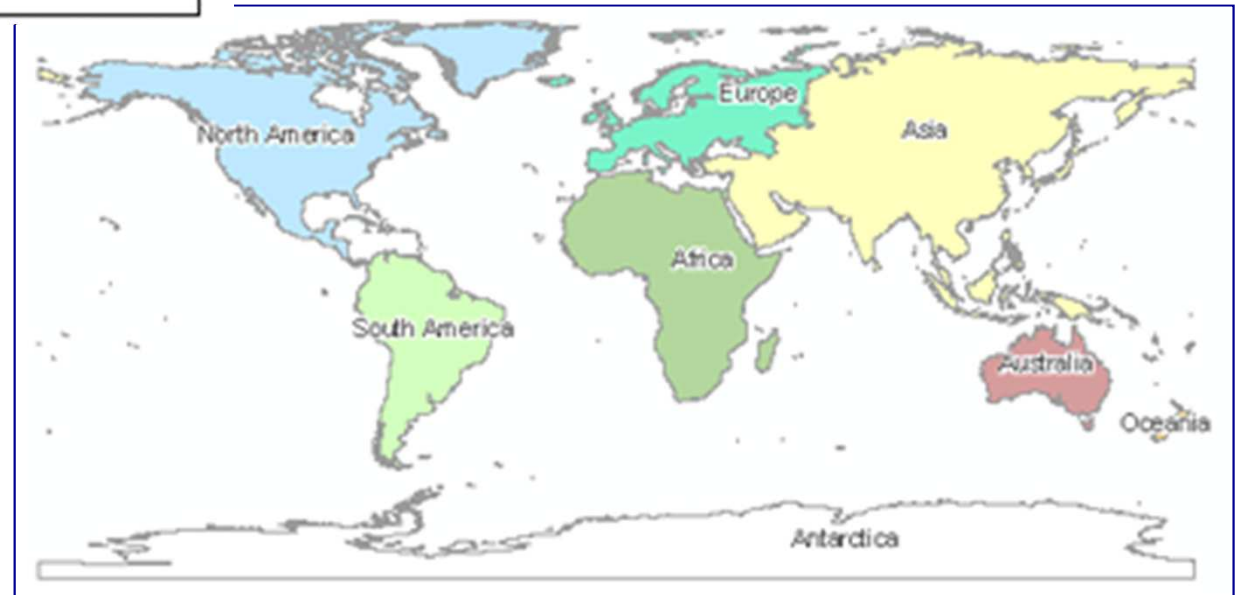
## Symbolizing feature data by attribute



# Mapping and Visualization

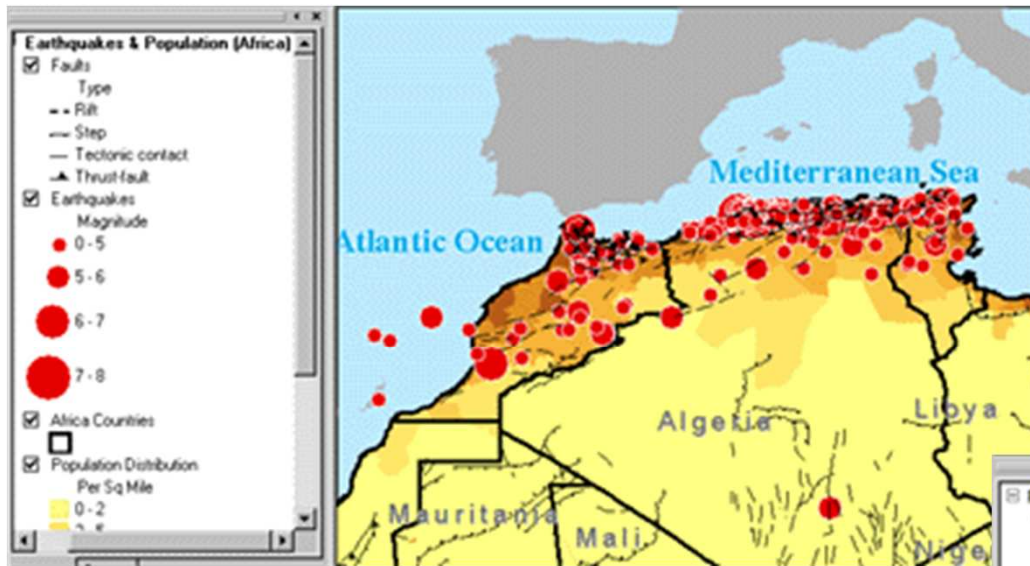


Symbolizing feature data by attribute (category)

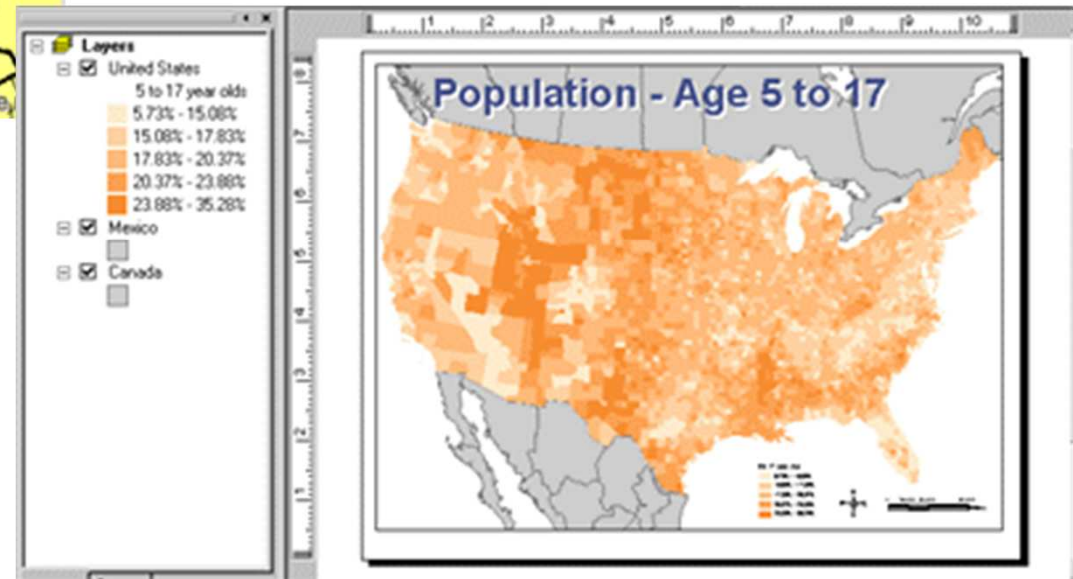




# Mapping and Visualization

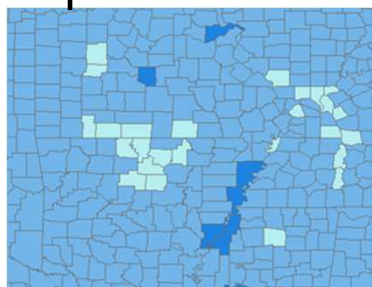


Symbolizing feature data by attribute (quantity)

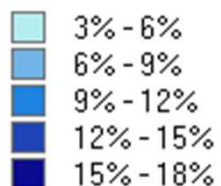




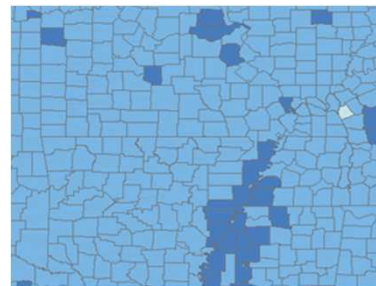
## Equal Interval



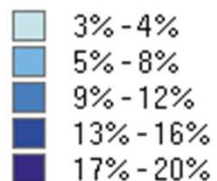
Percent Population  
Under 5



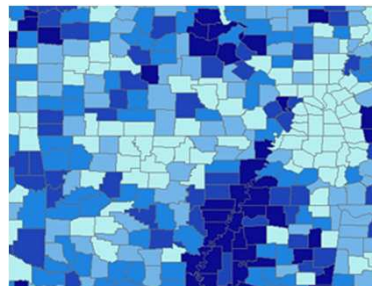
## Defined Interval



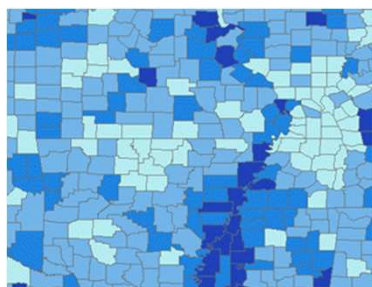
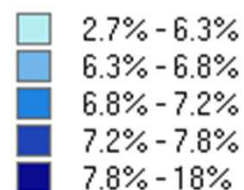
Percent Population  
Under 5



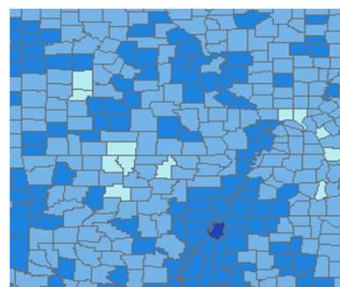
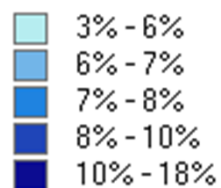
## Quantiles



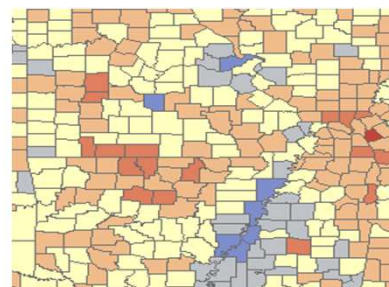
Percent Population  
Under 5



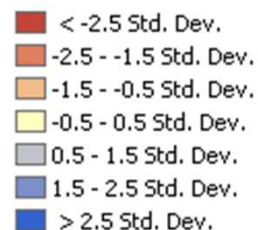
Percent Population  
Under 5



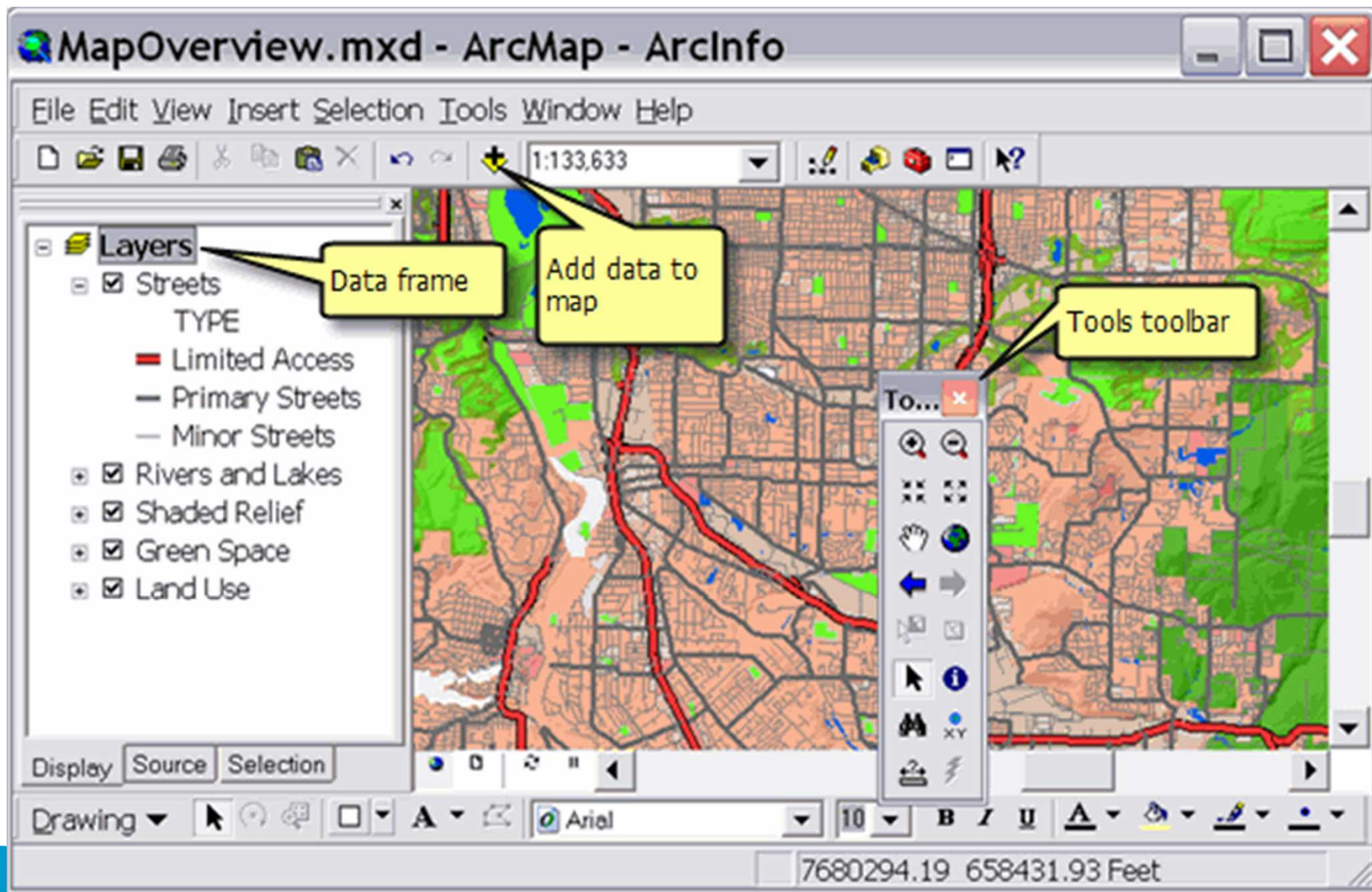
Percent Population  
Under 5



Population Under 5  
Deviation from Mean

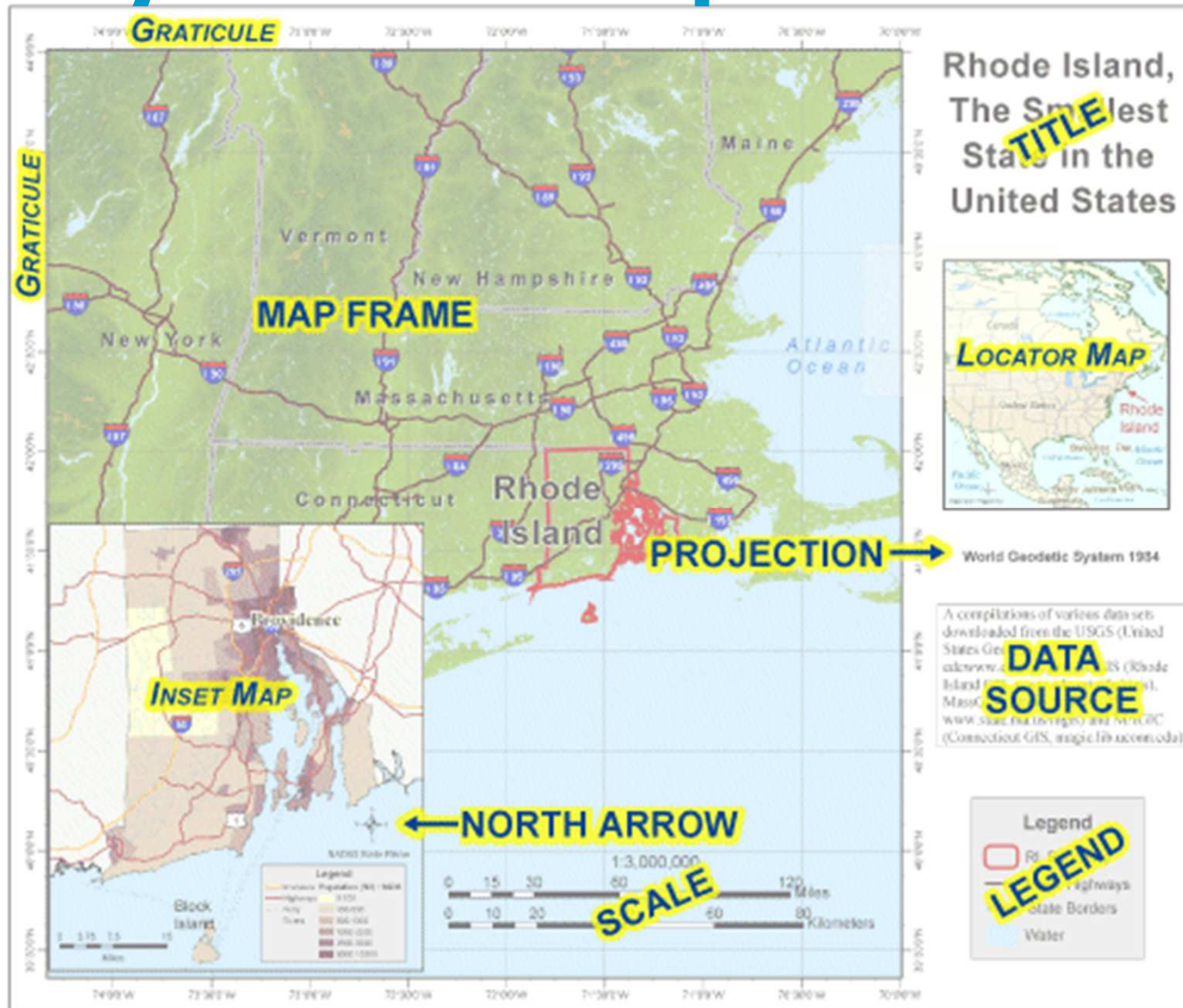


# ArcMap: Data Frame

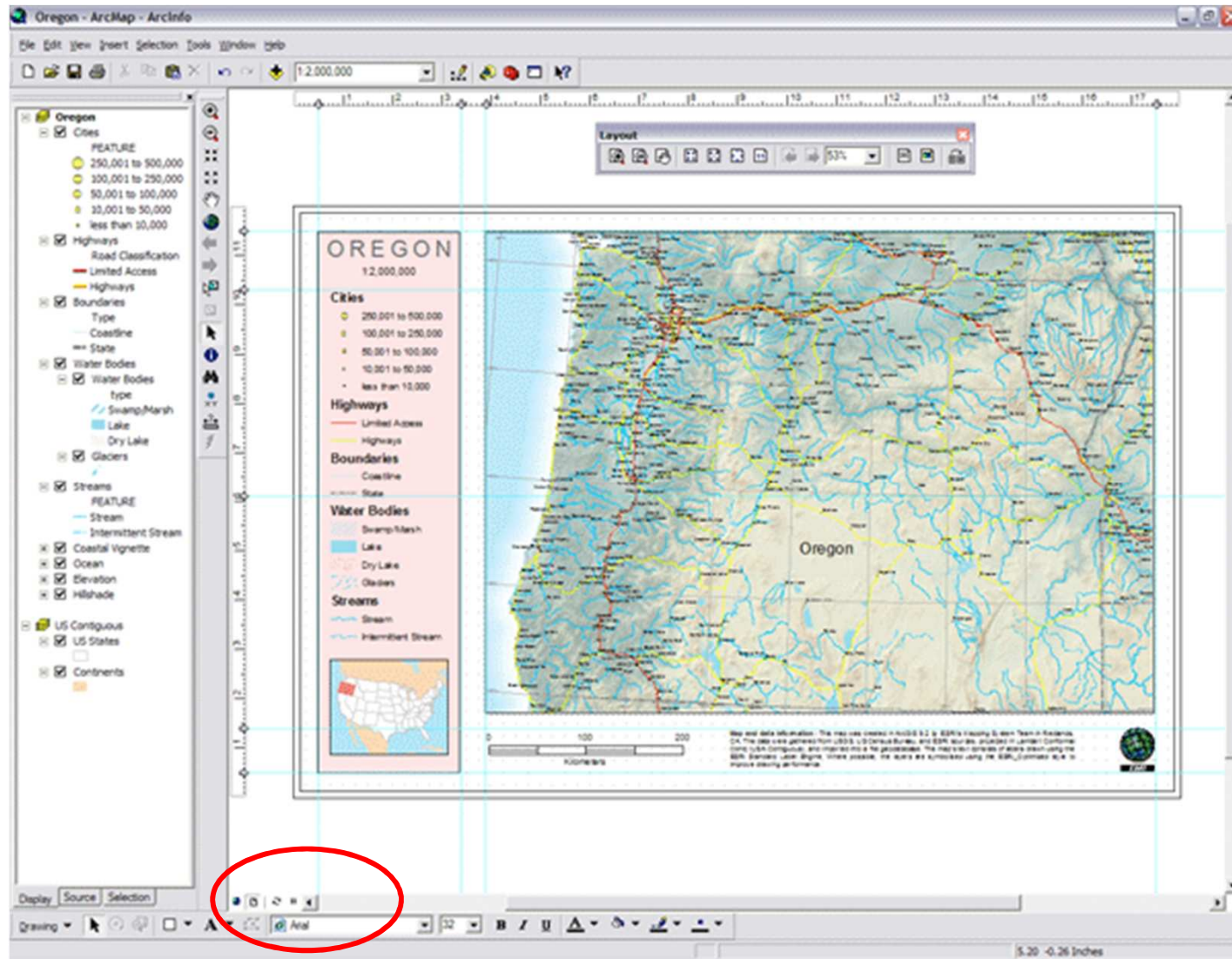




# Map layout and composition

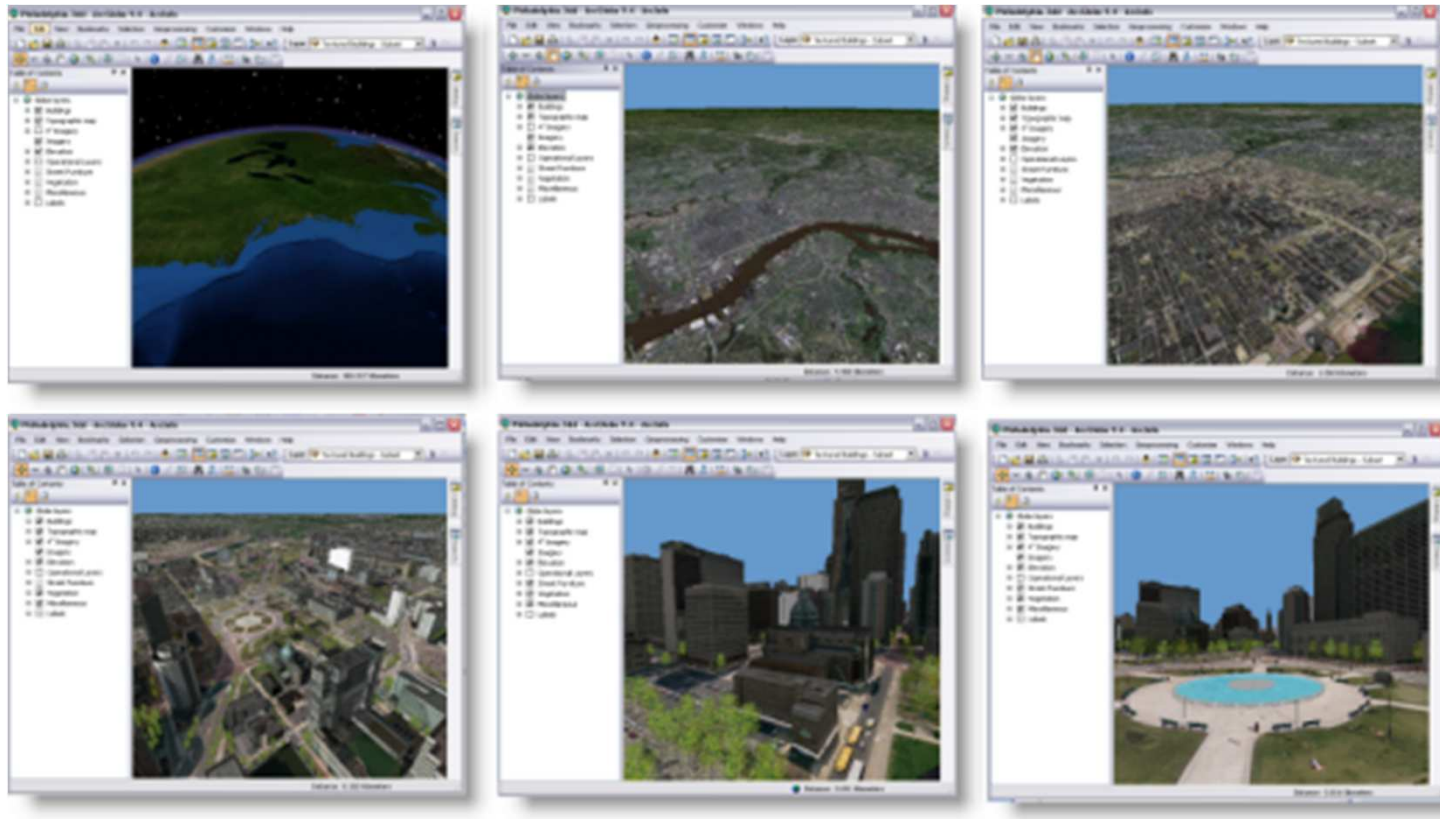


# ArcMap: The Map layout

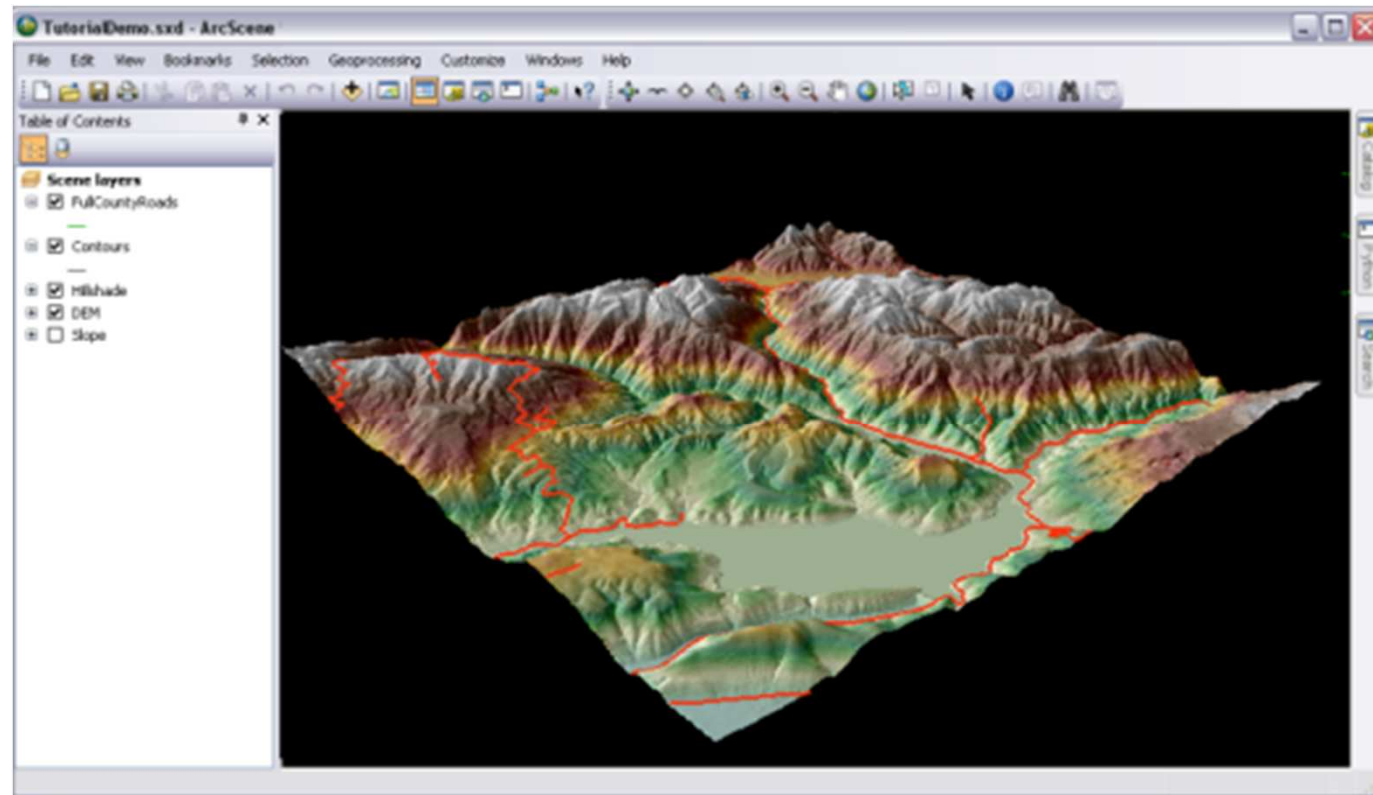




# Mapping and Visualization: ArcGlobe



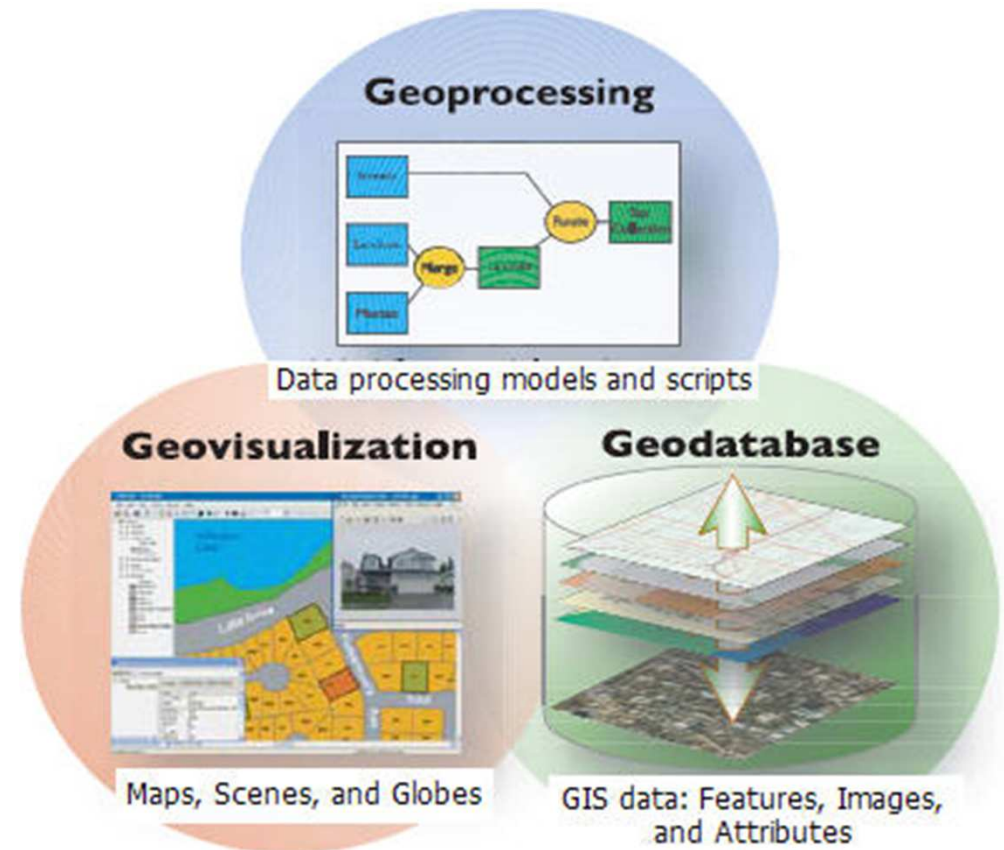
# Mapping and Visualization: ArcScene



# Geographical Information Systems

## Key functions of a GIS:

- Data management
- Mapping and Visualization
- ***Geoprocessing***



# Geoprocessing

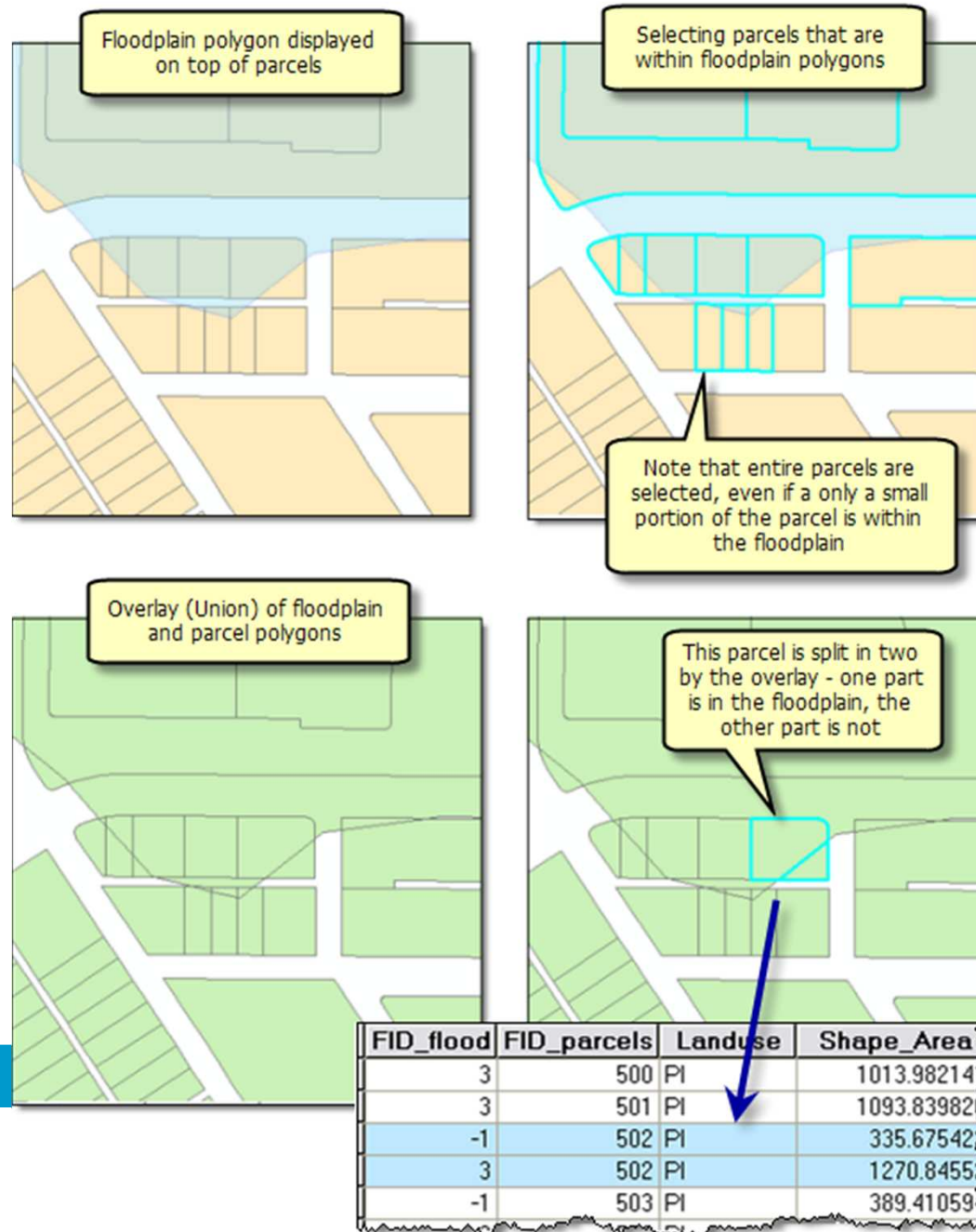
**Geoprocessing** = operating on geographic data  
to create new information



Goals: 1) To model a system  
2) To automate GIS tasks

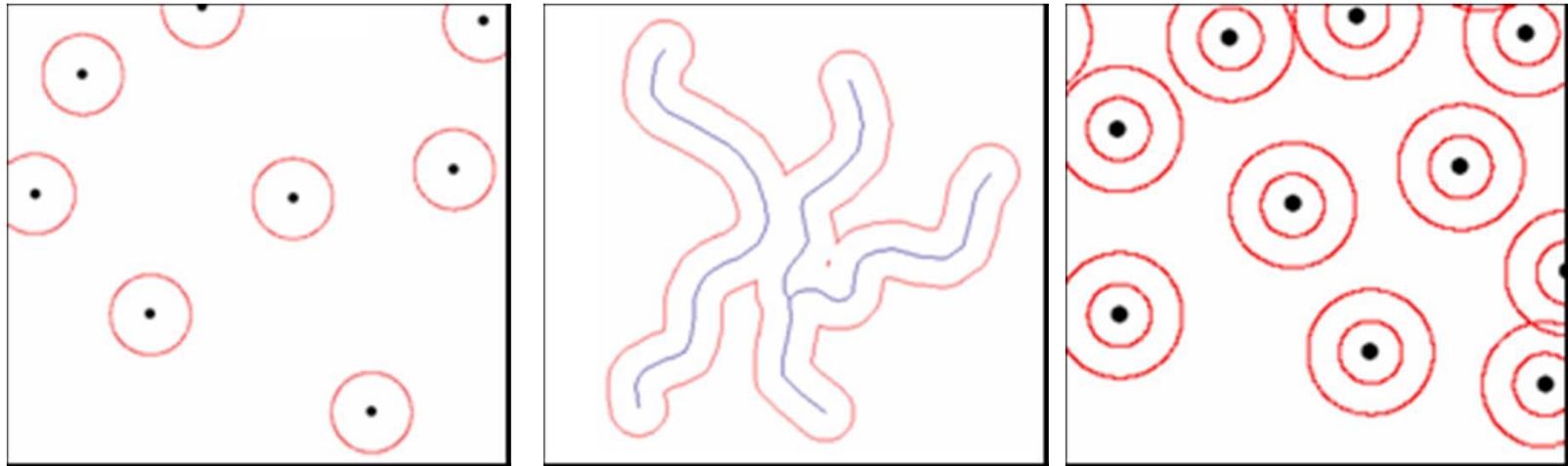


# Geoprocessing: Overlay Analysis

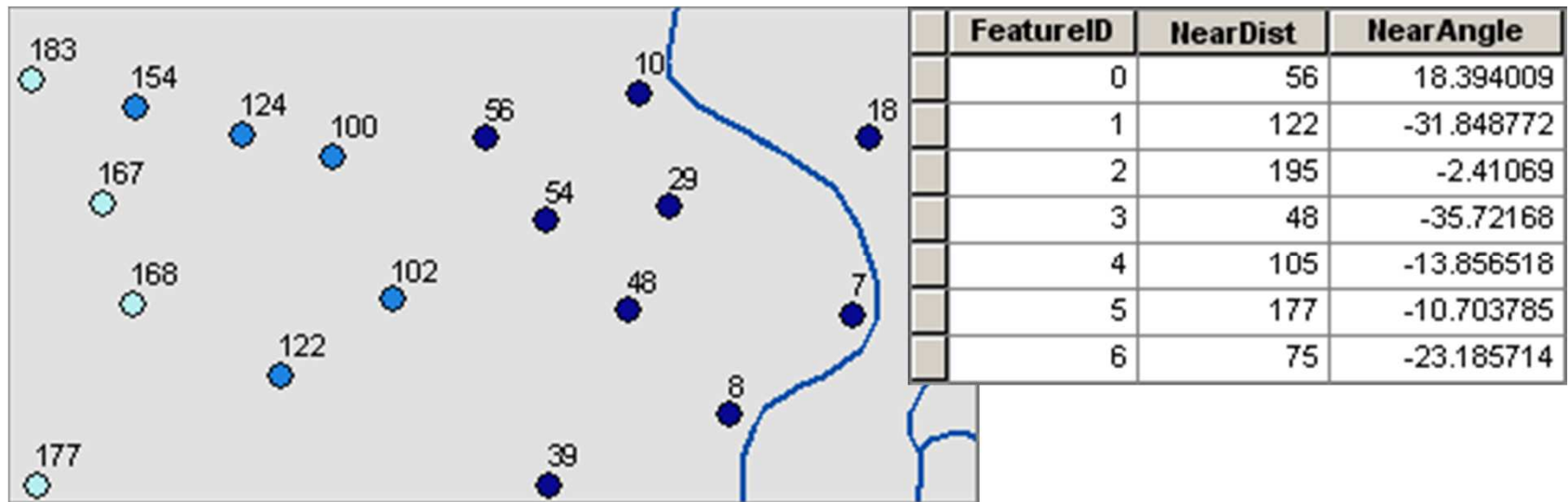


# Geoprocessing: Proximity Analysis

## Buffer

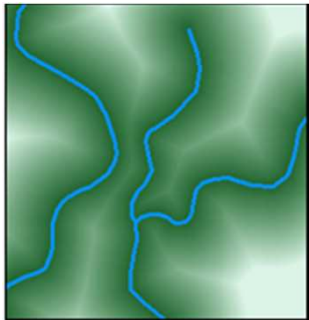


## Near



# Geoprocessing: Proximity Analysis

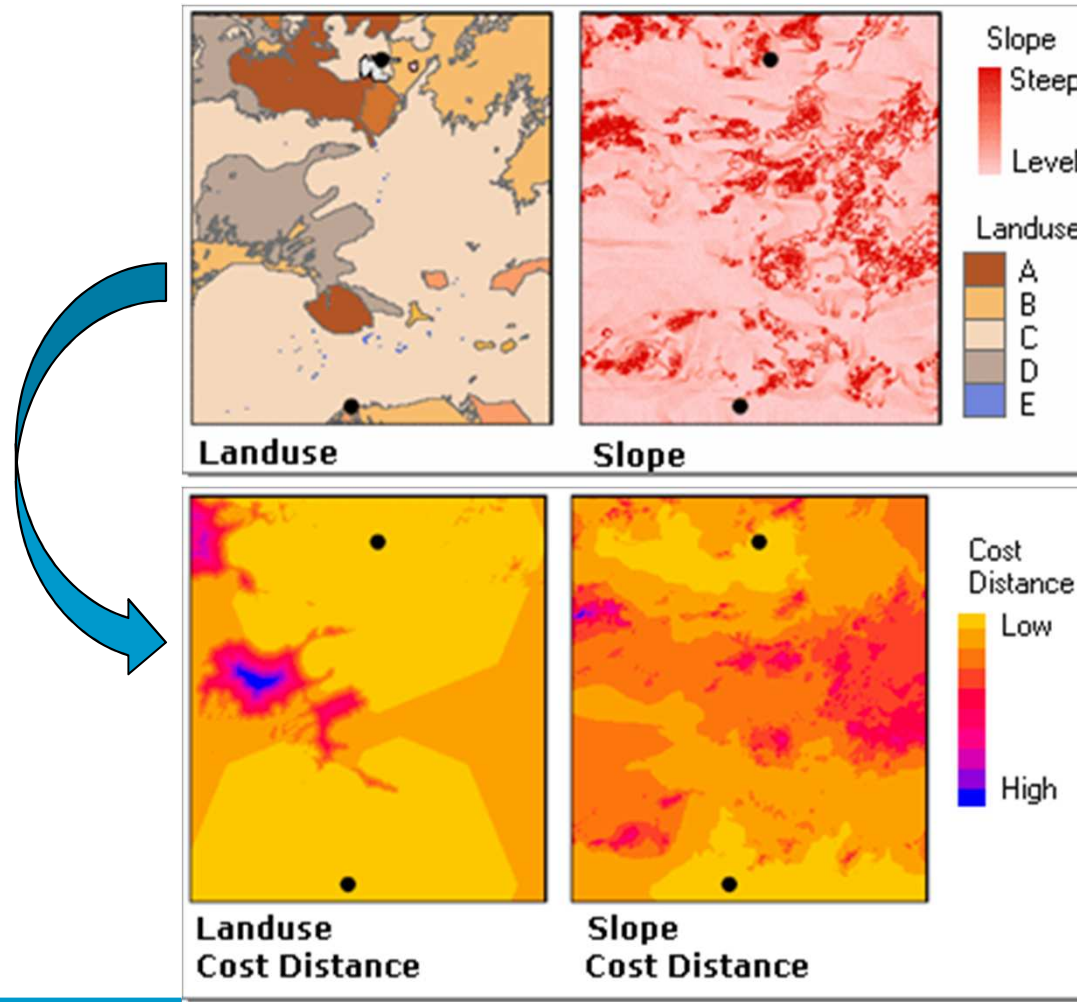
## Euclidean Distance



## Euclidean Allocation

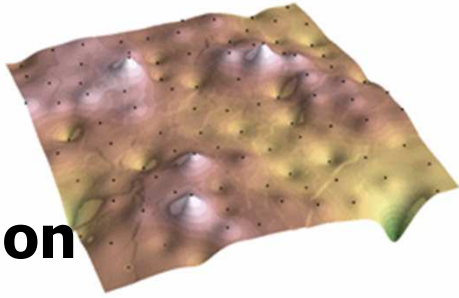


## Cost Distance

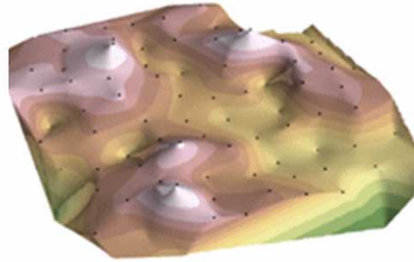


# Geoprocessing: Surface creation & analysis

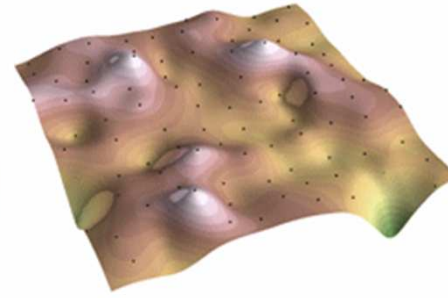
## Interpolation



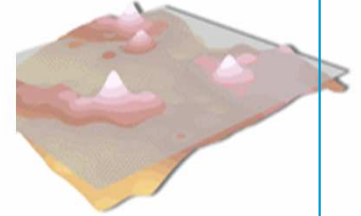
Inverse distance  
weighted



Natural  
neighbours

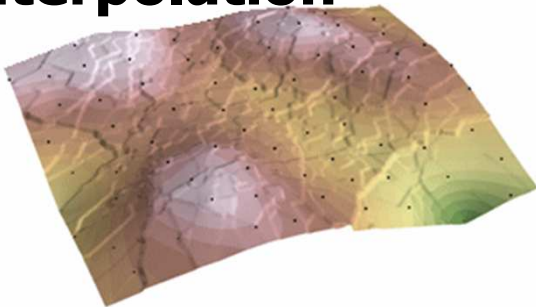


Spline

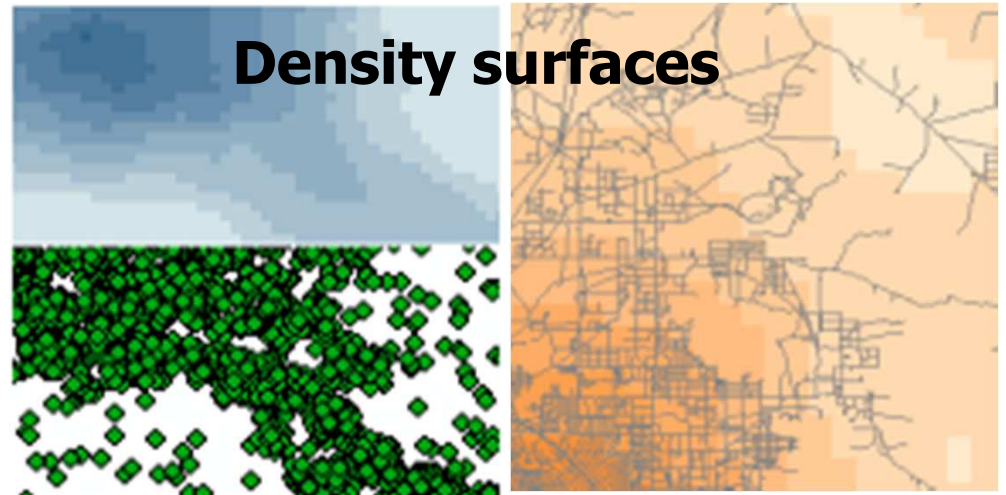


Trend

## Geostatistical Interpolation



## Density surfaces

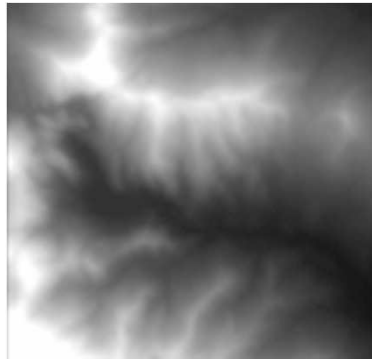




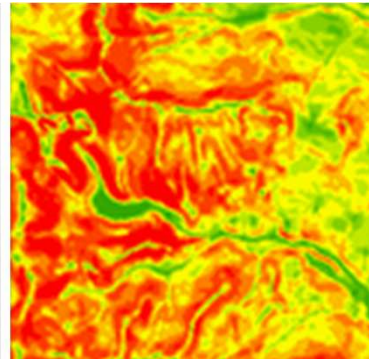
# Geoprocessing: Surface creation & analysis

## Terrain Analysis

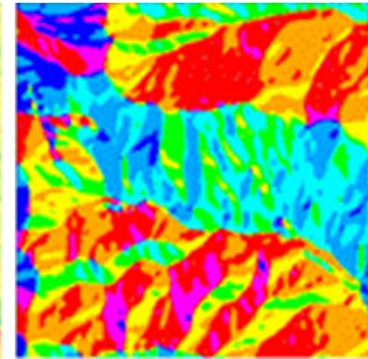
Elevation



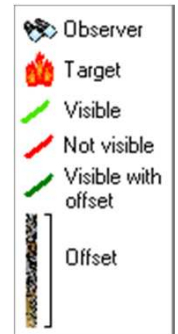
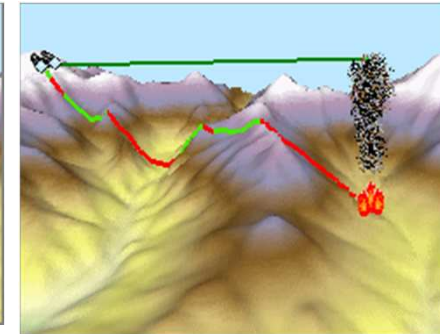
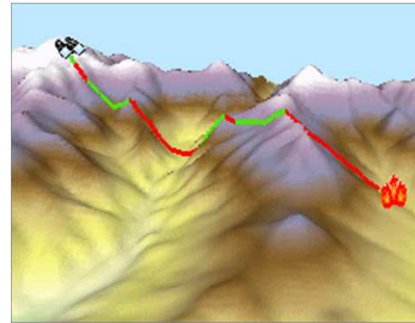
Slope



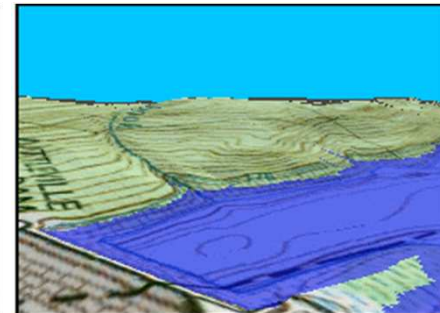
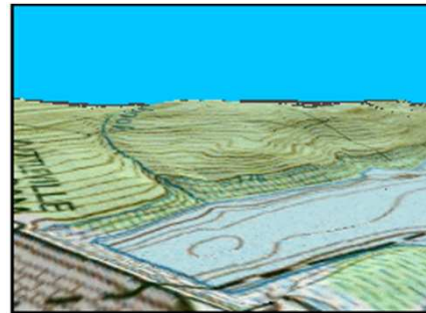
Aspect



## Visibility tools

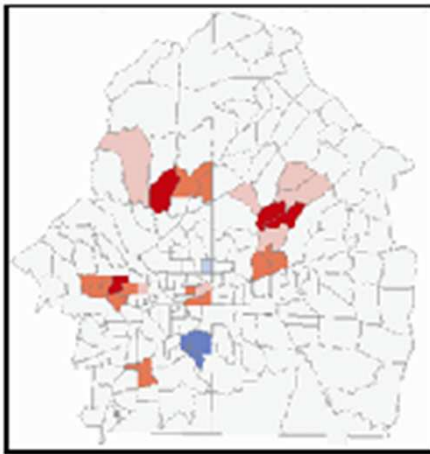


## Volume tools

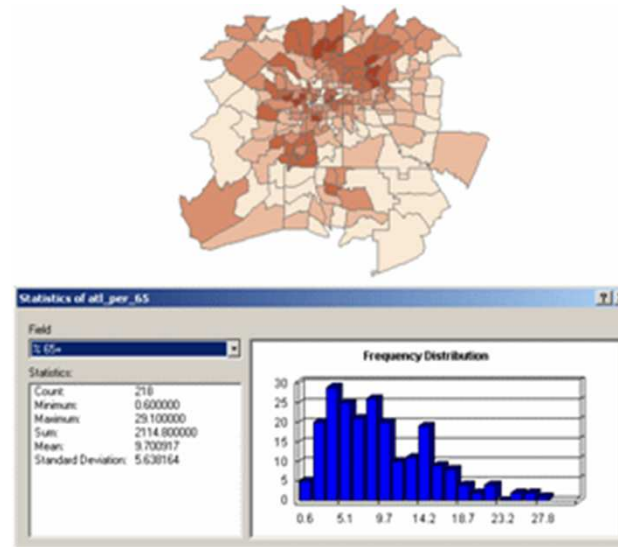


# Geoprocessing: Statistical Analysis

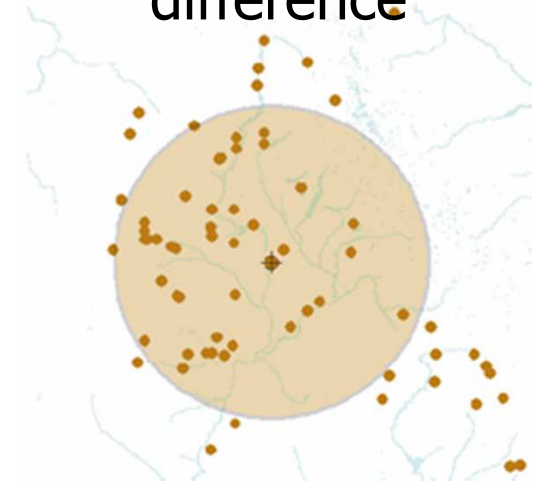
Statistical  
significance



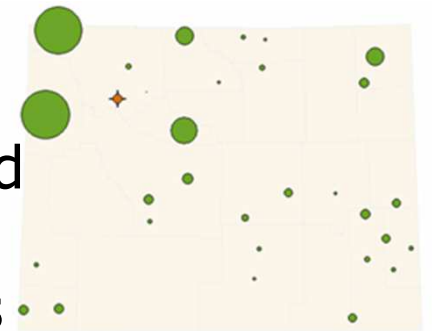
Summary statistics  
and histogram



Standard  
difference

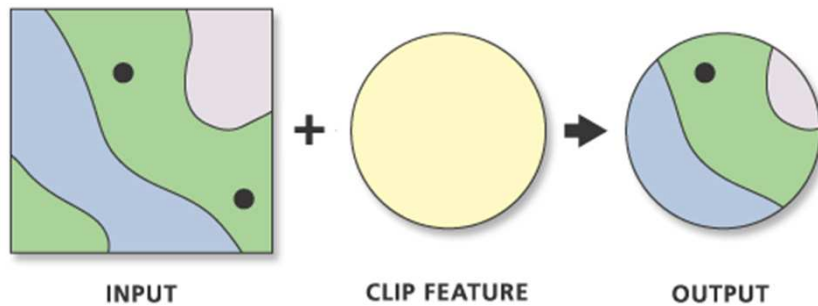


Weighted  
spatial  
statistics

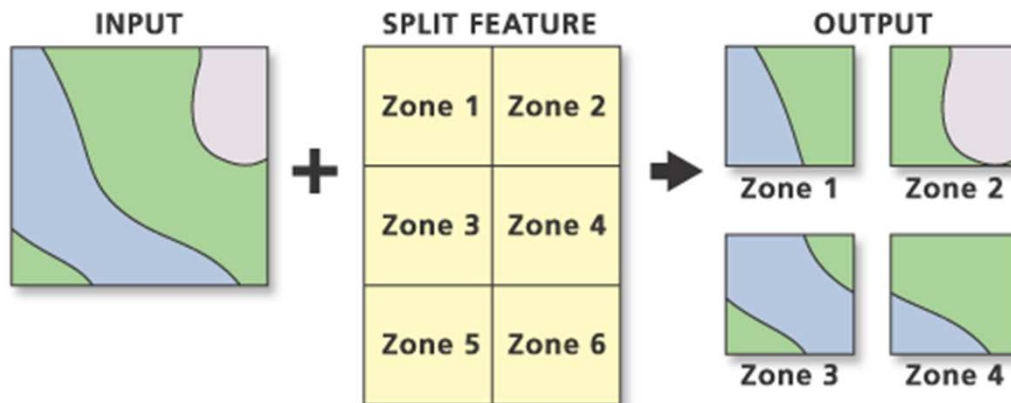


# Geoprocessing: Selecting and Extracting

## Clip



## Split



## Select (by Attribute or location)

The screenshot shows the **Attributes of canada2001** table in ArcMap. The table lists provinces and territories with their FID, Shape, KEY, NAME, NOM, and POP\_2001. The **Select By Attributes** dialog box is open, showing the **USA Countries** layer selected. The **Method** is set to **Create a new selection**. The **Where** clause is **"STATE\_NAME" = 'California'**. The map on the right shows the outline of California highlighted in red on a map of the United States.

FID	Shape*	KEY	NAME	NOM	POP_2001
0	Polygon	4800000	Alberta	Alberta	2789528
1	Polygon	5900000	British Columbia	Colombie-Britannique	3907738
2	Polygon	4600000	Manitoba	Manitoba	1119583
3	Polygon	1300000	New Brunswick	Nouveau-Brunswick	729498
4	Polygon	1000000			
5	Polygon	1200000			
6	Polygon	3500000			
7	Polygon	1100000			

# Activity: GIS data models for Water Resources Management

**For your task:**

- 1) Think of a “big” problem that could be solved using GIS.  
(Finding a location for something, designing a new piece of infrastructure, minimizing damage due to some event)**
- 2) What are the steps involved in solving your problem?**
- 3) Are there any tools that you’ve seen today that might be helpful?**

3 minutes - Think by yourself and make a list

10 minutes – Combine your list with the rest of your group and brainstorm

15 minutes - Share results with whole class.  
Do they have any additional suggestions?

(Each group appoint someone to write notes, and someone to present to whole class)



# GIS in Hydrology and Water Management

Using Delft-FEWS and Quantum GIS for flood forecasting in the Rhine

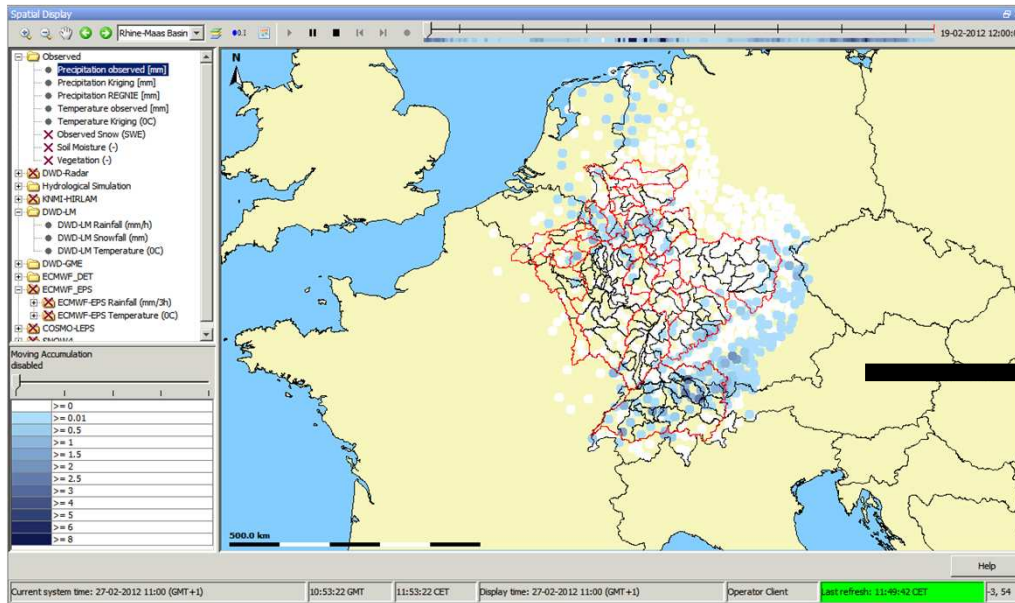
Jan Verkade,  
Water Resources Management, TU Delft  
& Deltares



# Interpolation of point data in Delft FEWS

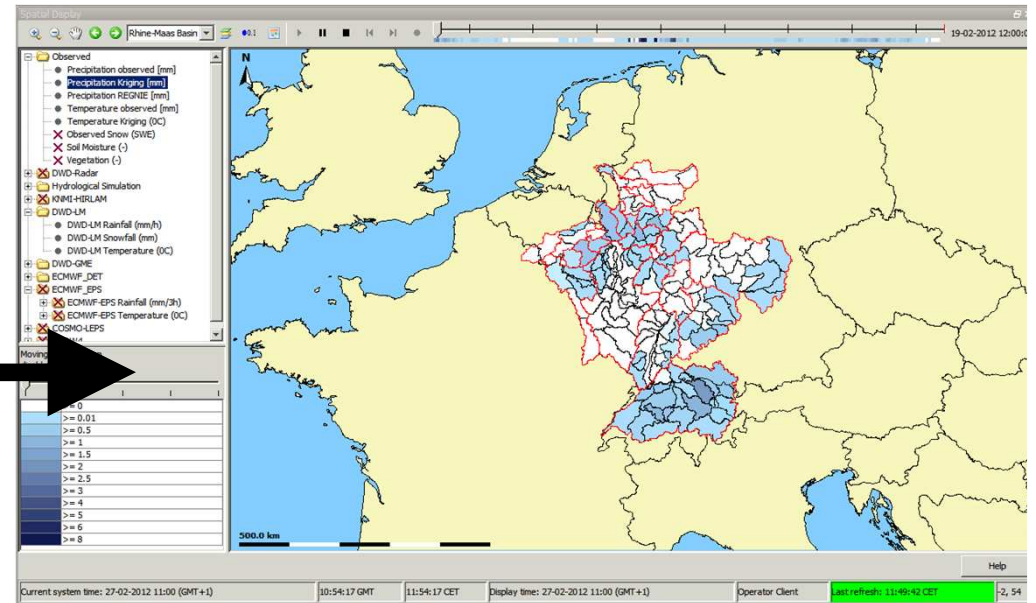
## Input:

Precipitation data at stations



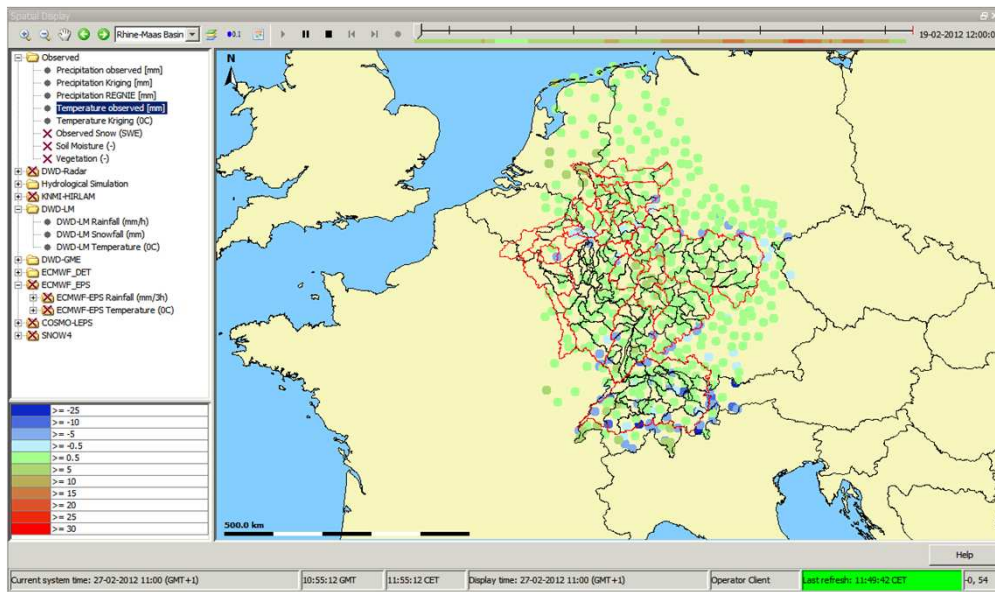
## Output:

Precipitation data for each HBV sub-basin

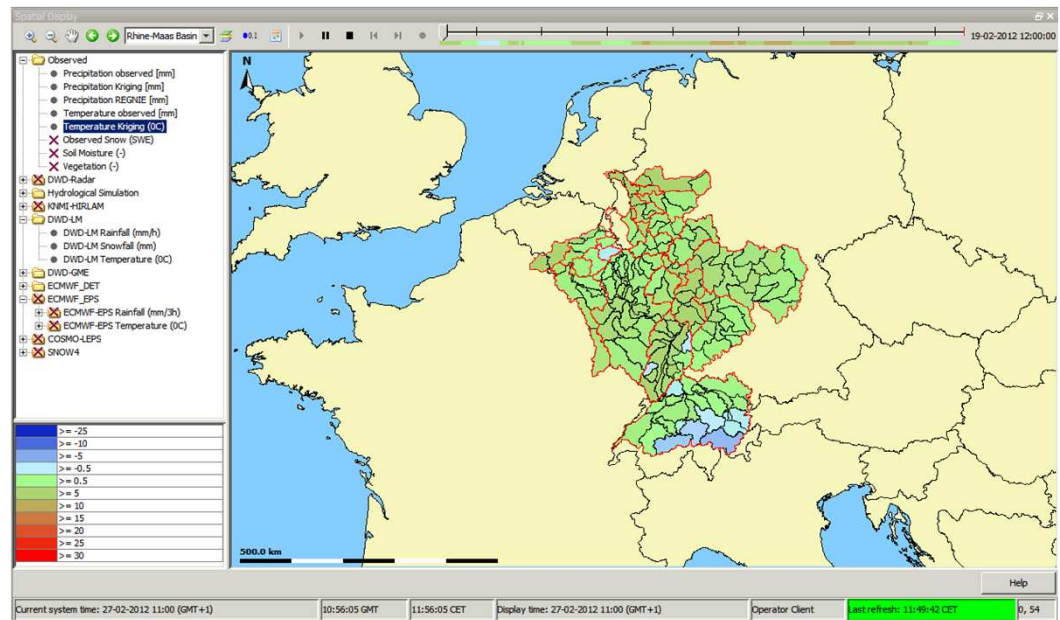


# Interpolation of point data in Delft FEWS

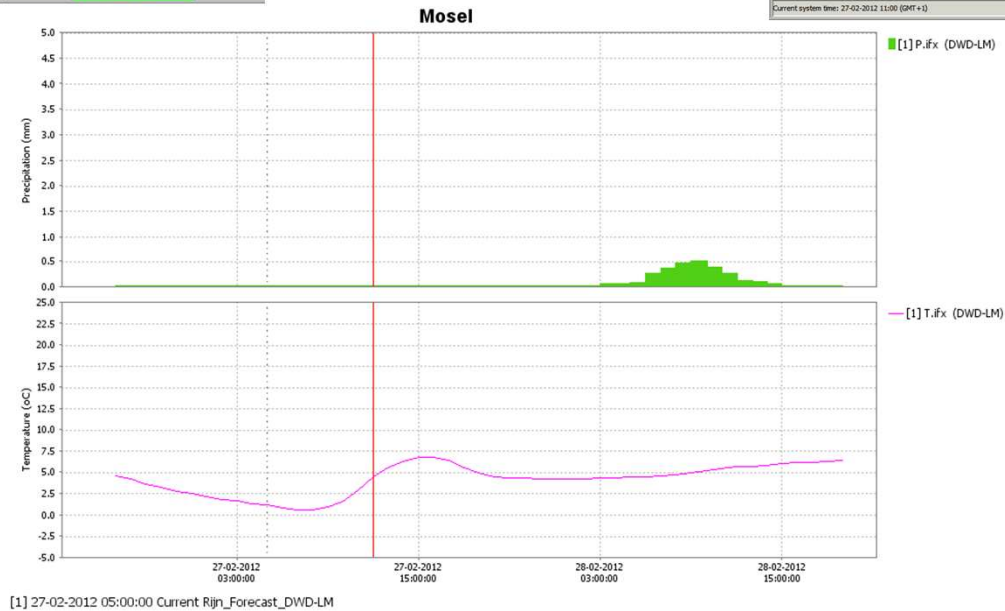
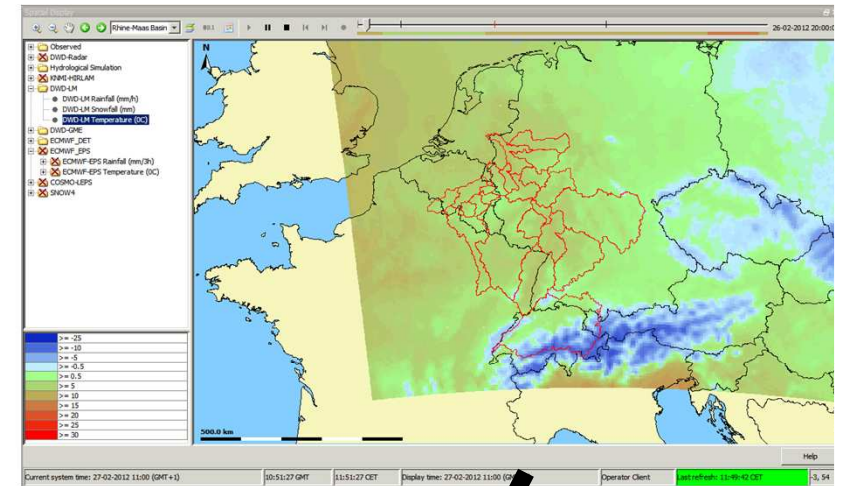
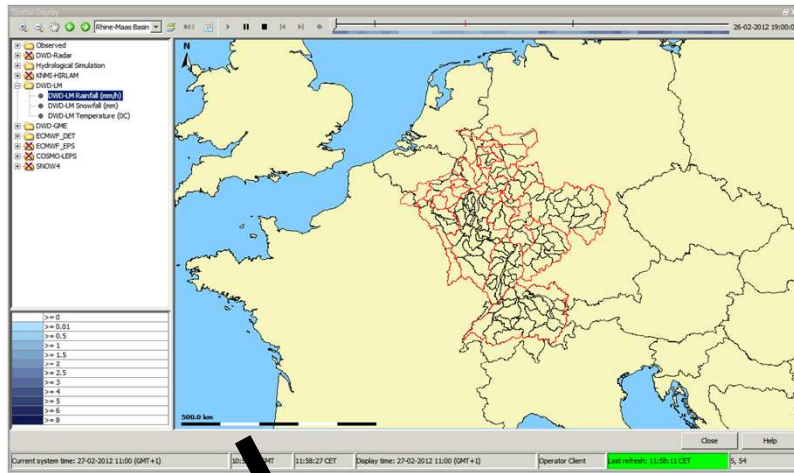
**Input:**  
Temperature data at stations



**Output:**  
Temperature data for each  
HBV sub-basin

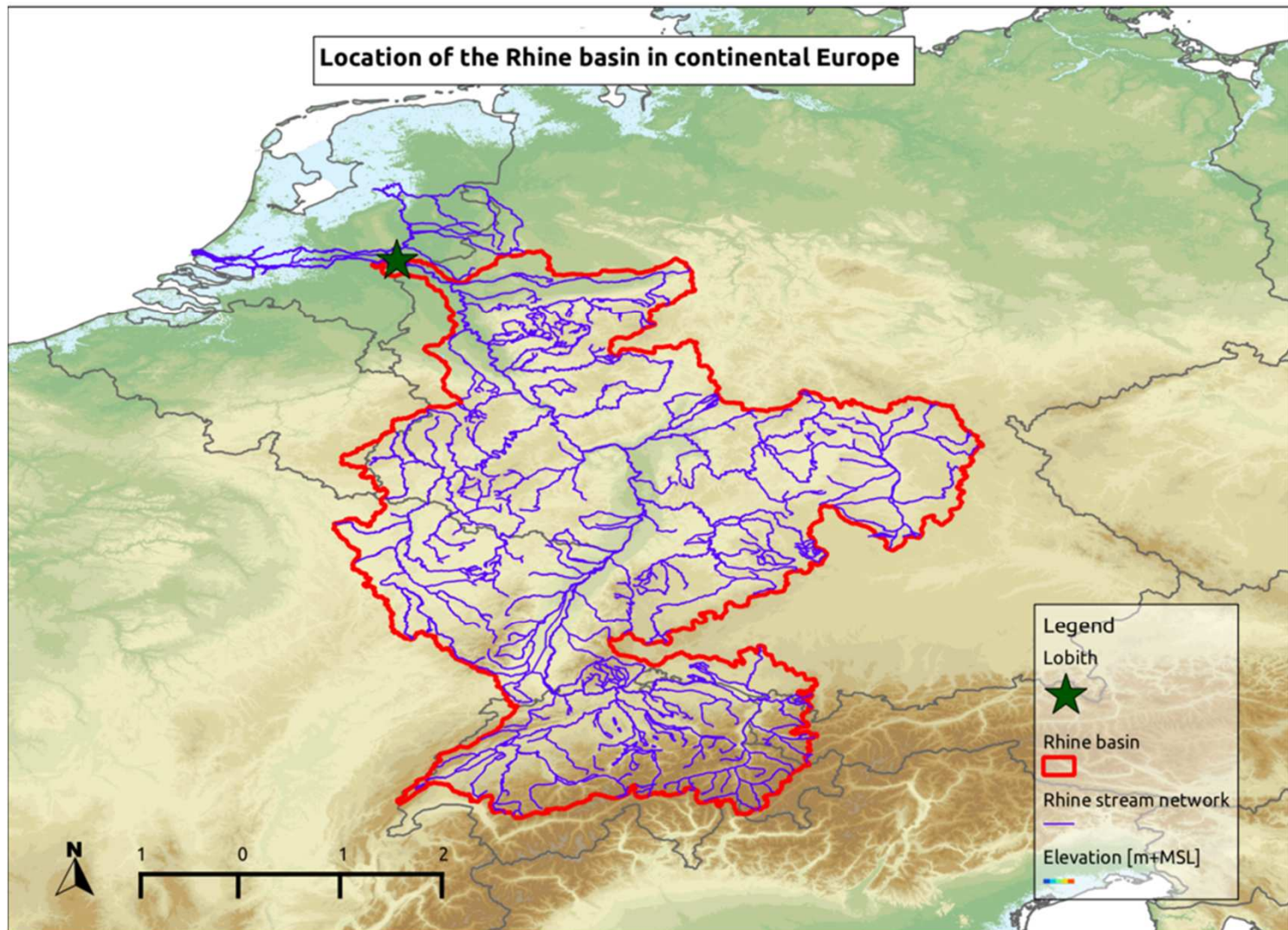


# Simulation in Delft-FEWS





# Visualization using Quantum GIS

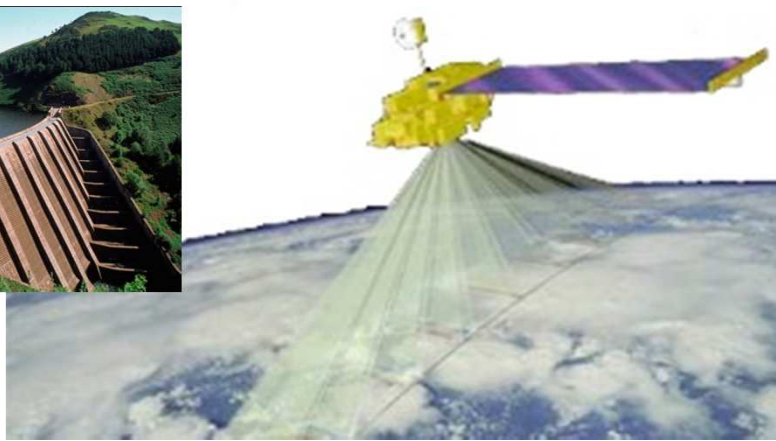




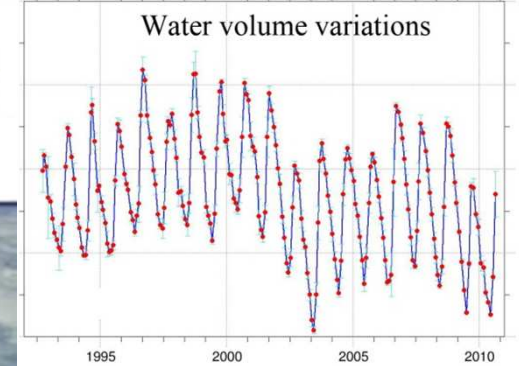
[2]



[3]



[4]



# GIS in Hydrology and Water Management

Estimating water volume variations in lakes and reservoirs using satellite altimetry and imagery data

Zheng Duan,  
Hydrology, TU Delft



# Introduction

Water volume variation is important

- availability for water allocation
- hydrological and climate change studies

Lack of in-situ data

- In-situ water levels
- Bathymetry map

Remote sensing offers global data

- Satellite imagery data → water surface areas
- Satellite altimetry data → water levels



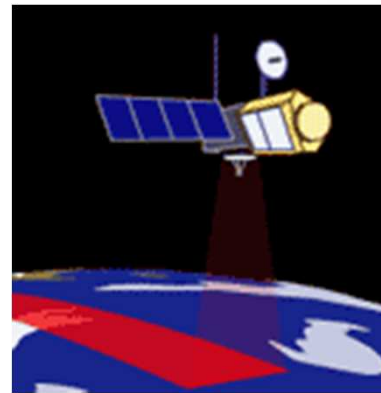
[5]

# Basic Principle of Satellite Altimetry

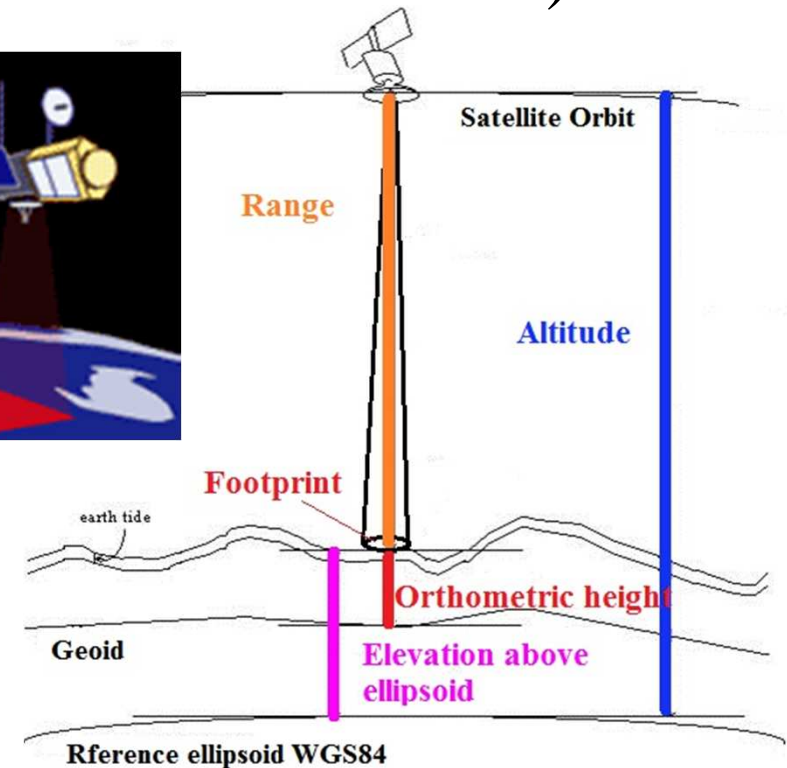
$\text{Height} = \text{Altitude} - \text{Range}(\text{corrected})$

Range (distance between satellite and water surface)

- Altitude of satellite
- Height



[6]

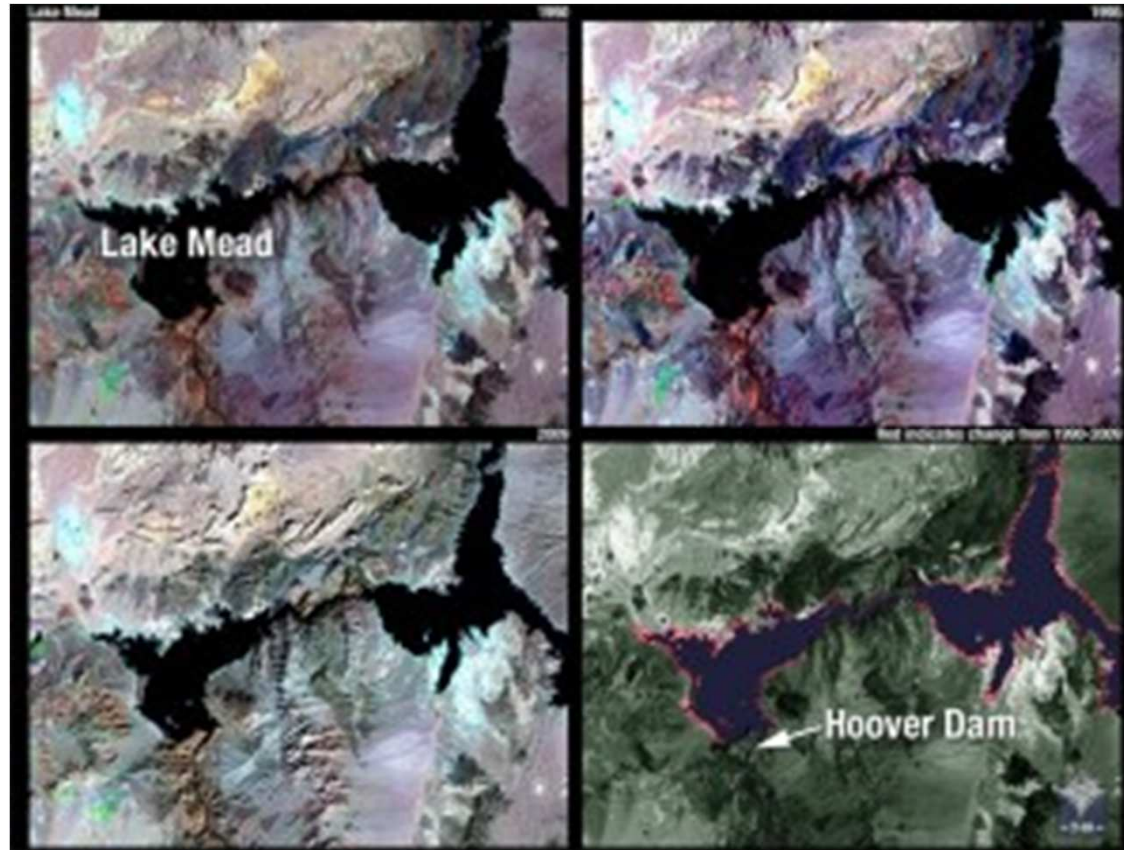


[7]

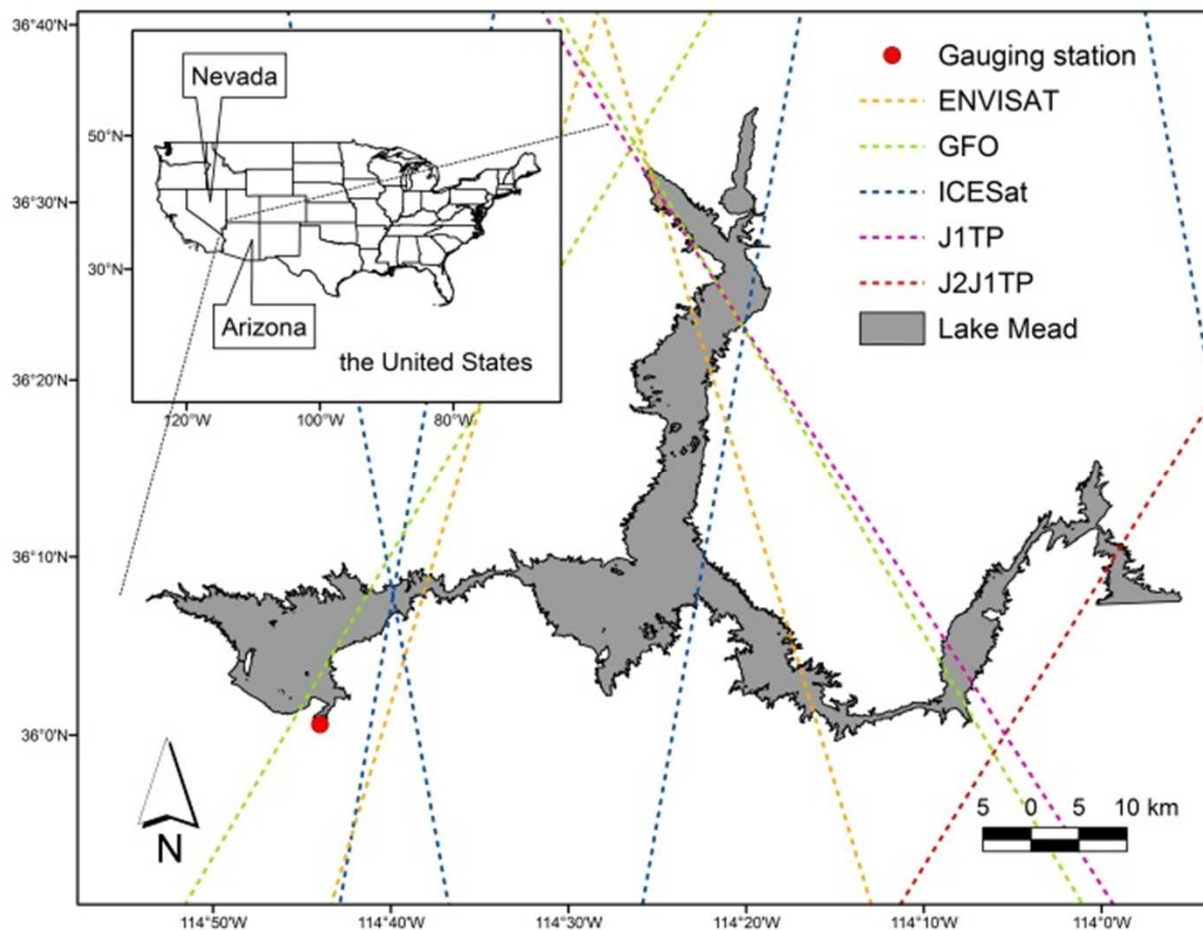
Finally time-series of water levels  
can be obtained from  
satellite altimetry



# Method: Land Classification using Landsat bands



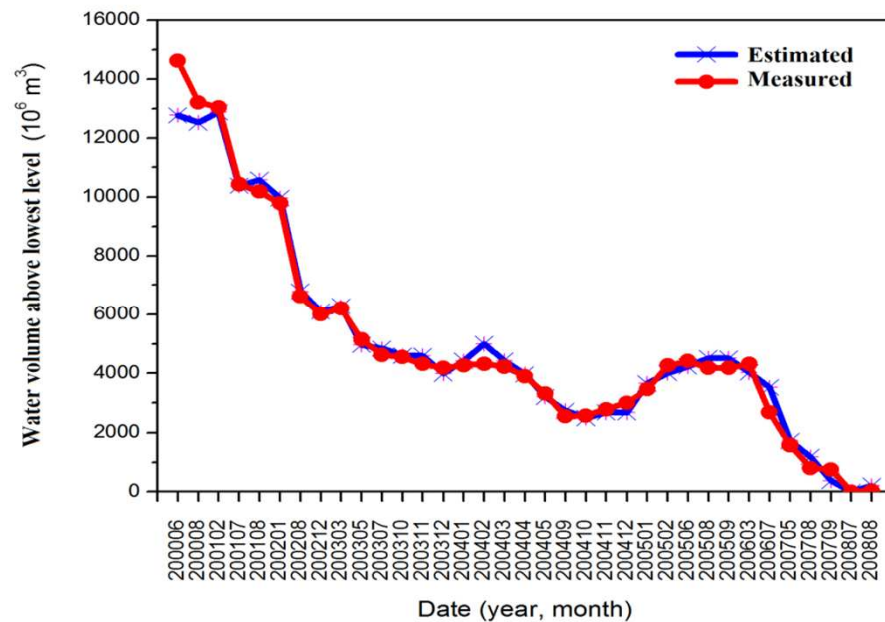
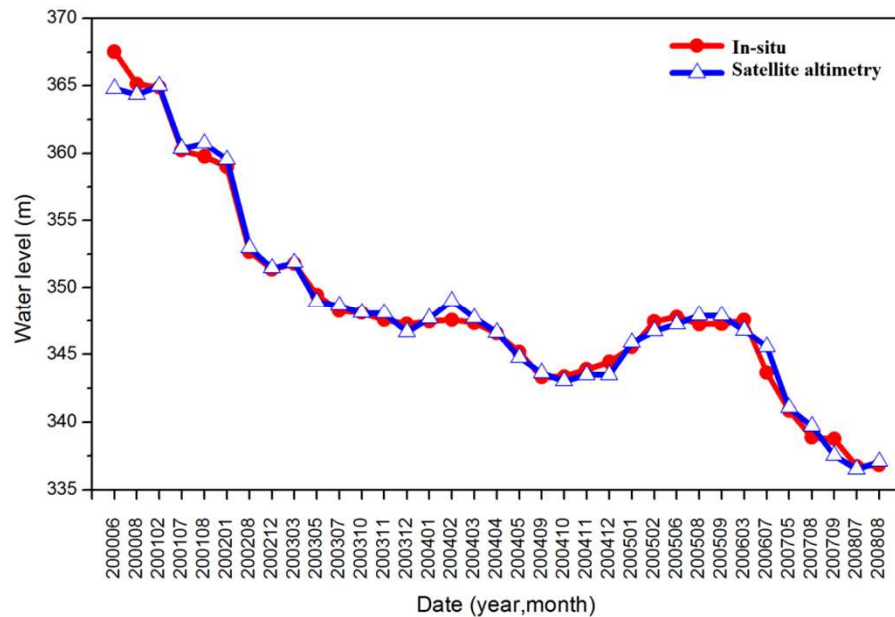
# Study area: Lake Mead



Characteristics	Lake Mead
Country	The U.S.A
Latitude	36° 31'-36° 05'N
Longitude	114° 02'-114° 00'E
Maximum Length (km)	180
Maximum width (km)	13
Length of shoreline (km)	890
Maximum depth (m)	150
Mean depth (m)	69
Lake area (km <sup>2</sup> )	640
Water volume (km <sup>3</sup> )	35.2

In Figure: ENVISAT, GFO, ICESat, J1TP and J2J1TP are flying tracks for different satellite altimetry missions

# Results



Water level: In-situ vs. satellite altimetry-derived

**Water volume variation can be derived using only satellite data within 10% accuracy**

Water volume:

In-situ vs. Estimated using satellite altimetry and satellite imagery data

Period	No.	R <sup>2</sup>	RMSE( $10^6 \text{ m}^3$ )
2000-2008	35	0.99	428

# GIS in Hydrology and Water Management

GIS to enable IWRM: Early assessments on the use of groundwater for intensive farming in the Chaco-Pampean plains – Argentina

Santiago Gaitan,  
Water Resources Management, TU Delft

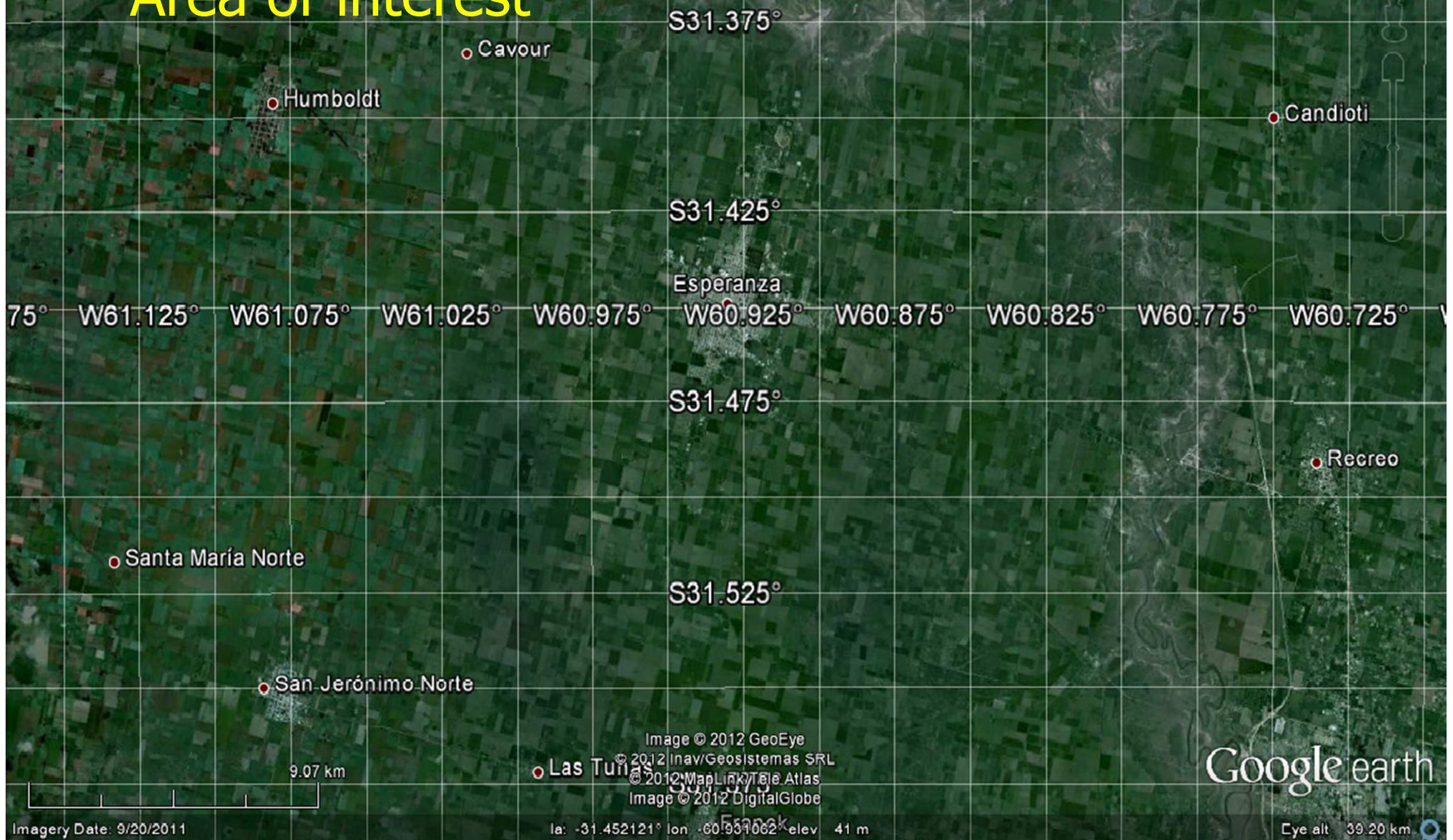








# Area of interest



# Problem Definition

## **Water availability**

- Mild temperature climate:
  - Rainfall  $\sim$  930mm/year
  - Rainfall excess  $\sim$  40mm/year
- Relatively well drained soils
- Surface water not enough for irrigation.
- GW pumped from aquitard beyond a phreatic aquifer
- Growing, intensive farming of soybean and wheat to supply emerging international markets.
- Environment becoming very prone to droughts.

# Problem Definition

## Challenges

- Competitive use of the groundwater resource for drinking, industrial and agricultural purposes.
- Agricultural water discharge (with a potential agrochemical-pollutant charge).
- No measurement, registry nor control of the pumped water for irrigation.
- Incipient law enforcement actions on soil and water resources exploitation.
- Very limited surveying power. Lack of accurate environmental data.

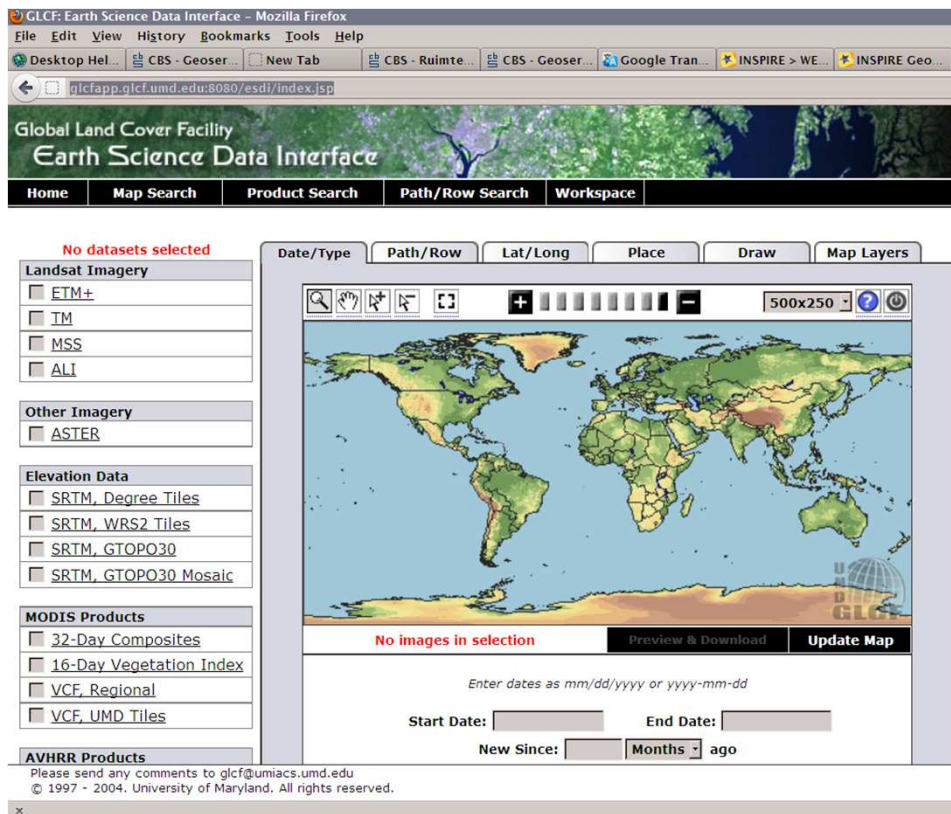


# Landsat Imagery

Land use characterization & calculation of vegetation indexes

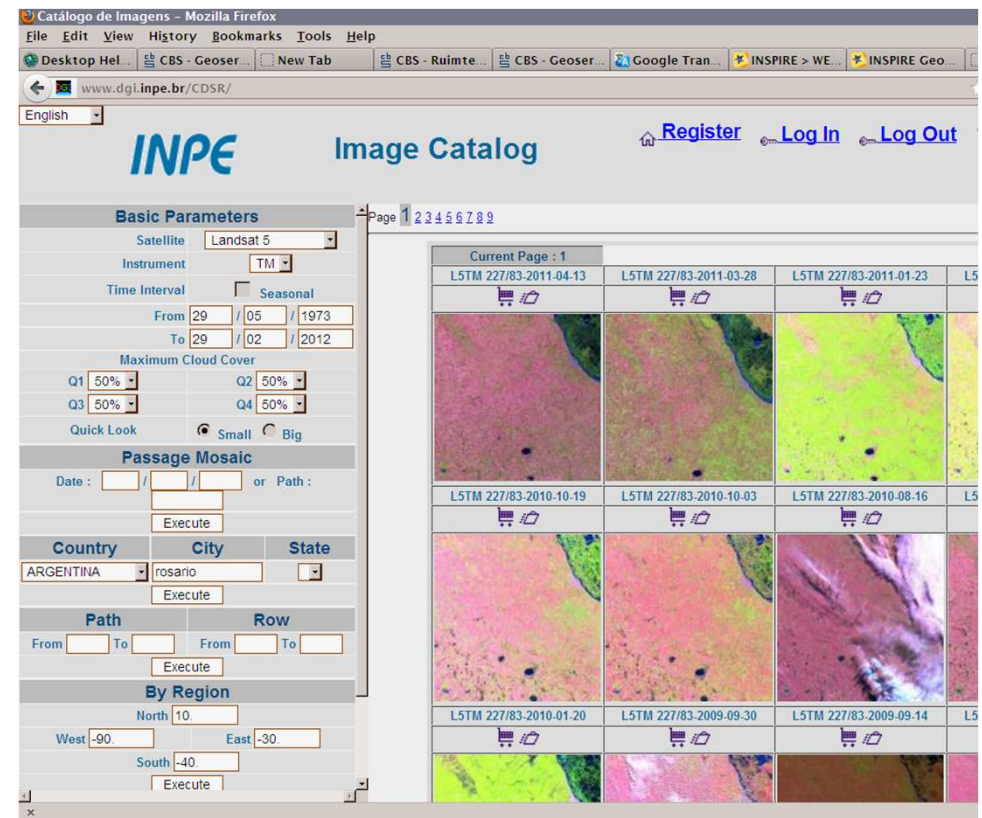
Global Land Cover Facility – USA

<http://glcf.umiacs.umd.edu/>



Divisão de Geração de Imagens - Brazil

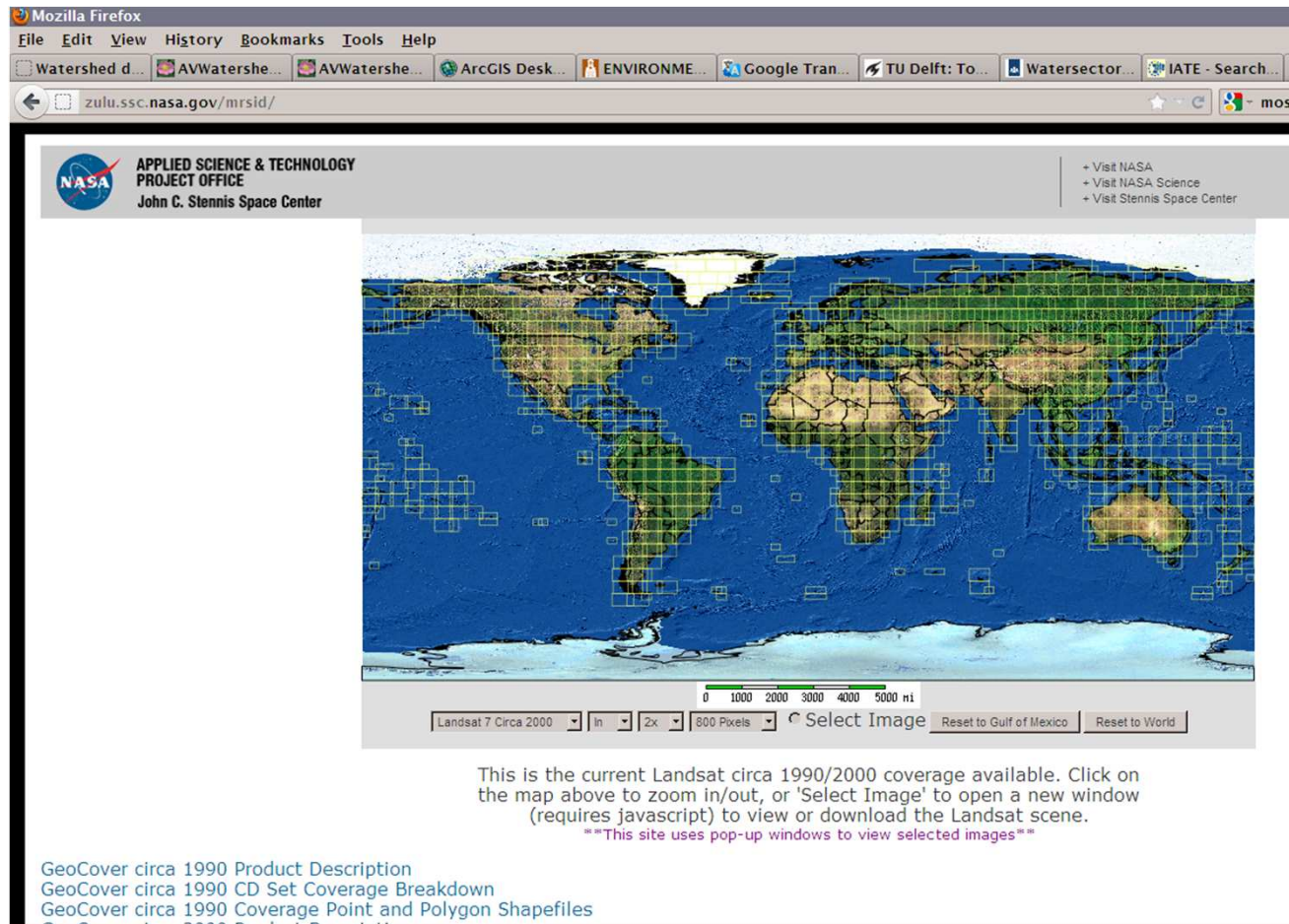
<http://www.dgi.inpe.br/CDSR/>



# Reference raster for registration

Geocover resource from National Aeronautics and Space Administration - USA

<http://zulu.ssc.nasa.gov/mrsid/>



# Data: Digital Elevation Model

Topography &  
Watershed  
delineation

ASTER Global Digital Elevation Model –  
Japan & USA

<http://www.gdem.aster.ersdac.or.jp>

Features of ASTER G-DEM – Mozilla Firefox

File Edit View History Bookmarks Tools Help

Watershed d... AVWatershe... AVWatershe... ArcGIS Desk... ENVIRONME... Google Tran... TU Delft: To... Watersector... IATE - Search

www.ersdac.or.jp/GDEM/E/2.html

### ASTER Global Digital Elevation Model (GDEM) ASTER全球3次元地形データ

Overview Features Notes Information

#### Outline of ASTER GDEM

- \* Global DEM for all the land area covered by ASTER.
- \* Enhanced accuracy due to the use of multiple ASTER images over the same area.
- \* User-friendly, allowing selective cropping.

Concept of ASTER G-DEM development

ASTER data (60km x 60km)

Generation of seamless DEM using all ASTER data ever acquired over the target area

Automated processing

A seamless wide-coverage DEM

ASTER GDEM

Easy to use, allowing for selective cropping

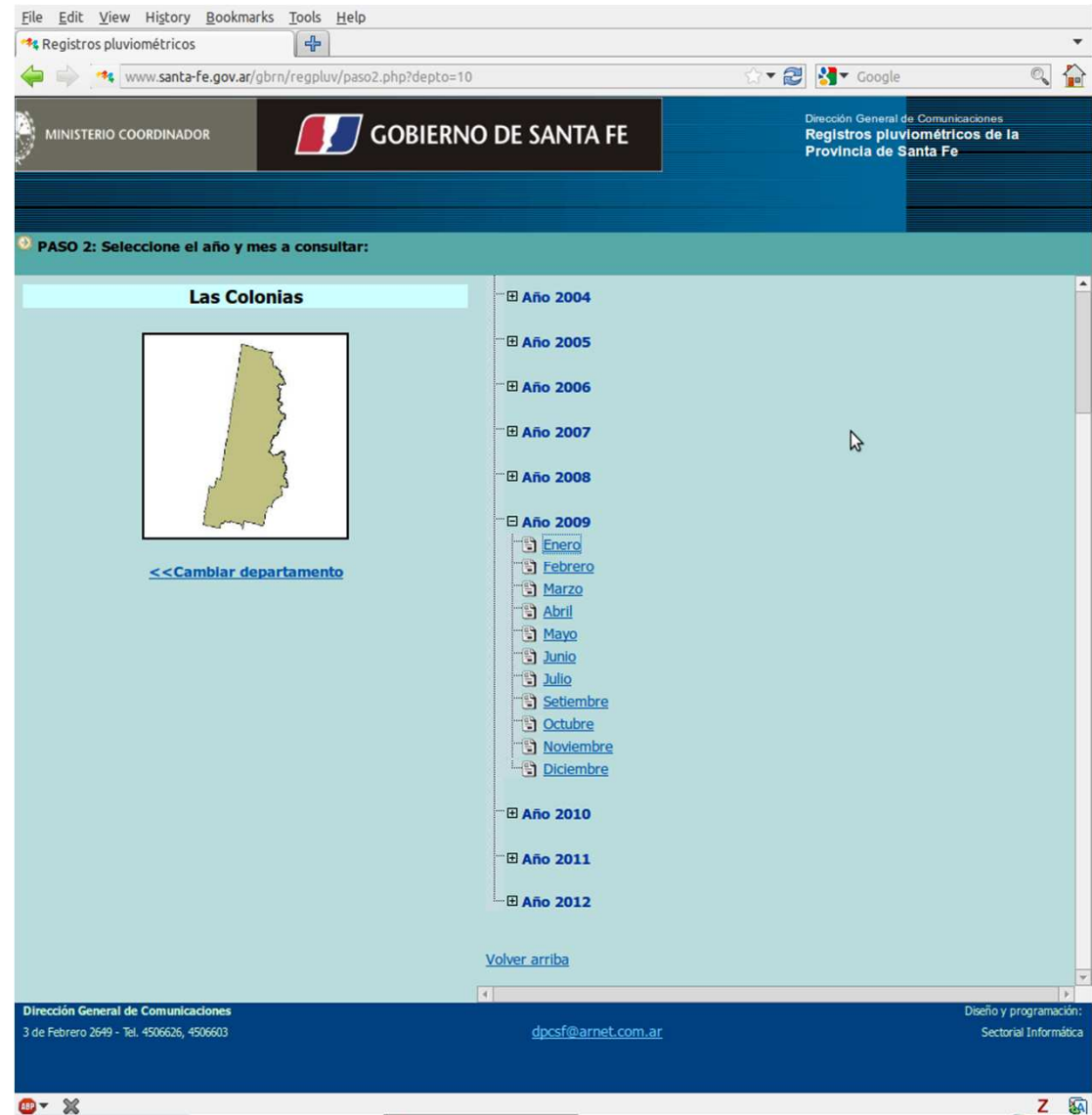
Red-colored area: ASTER coverage (available area for GDEM generation) (Deeper red indicates more frequent observations, thus providing higher accuracy)



# Rainfall data

Pluviometric registries from  
local gauges in Argentina

<http://www.santa-fe.gov.ar/gbrn/regpluv/>







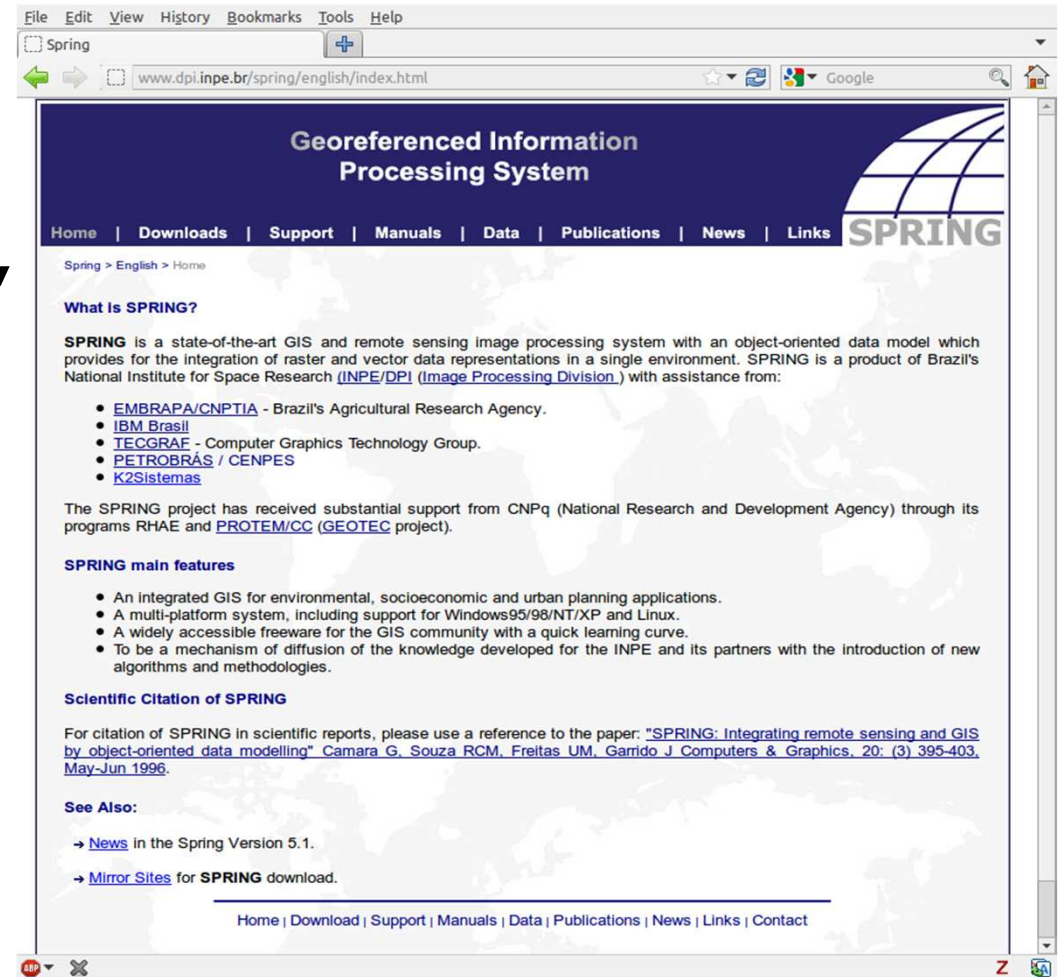
# Image processing software (with GIS capabilities)

**SPRING**

**(Sistema de Processamento de  
Informações Georreferenciadas),**

**National Institute for Space  
Research – Brazil**

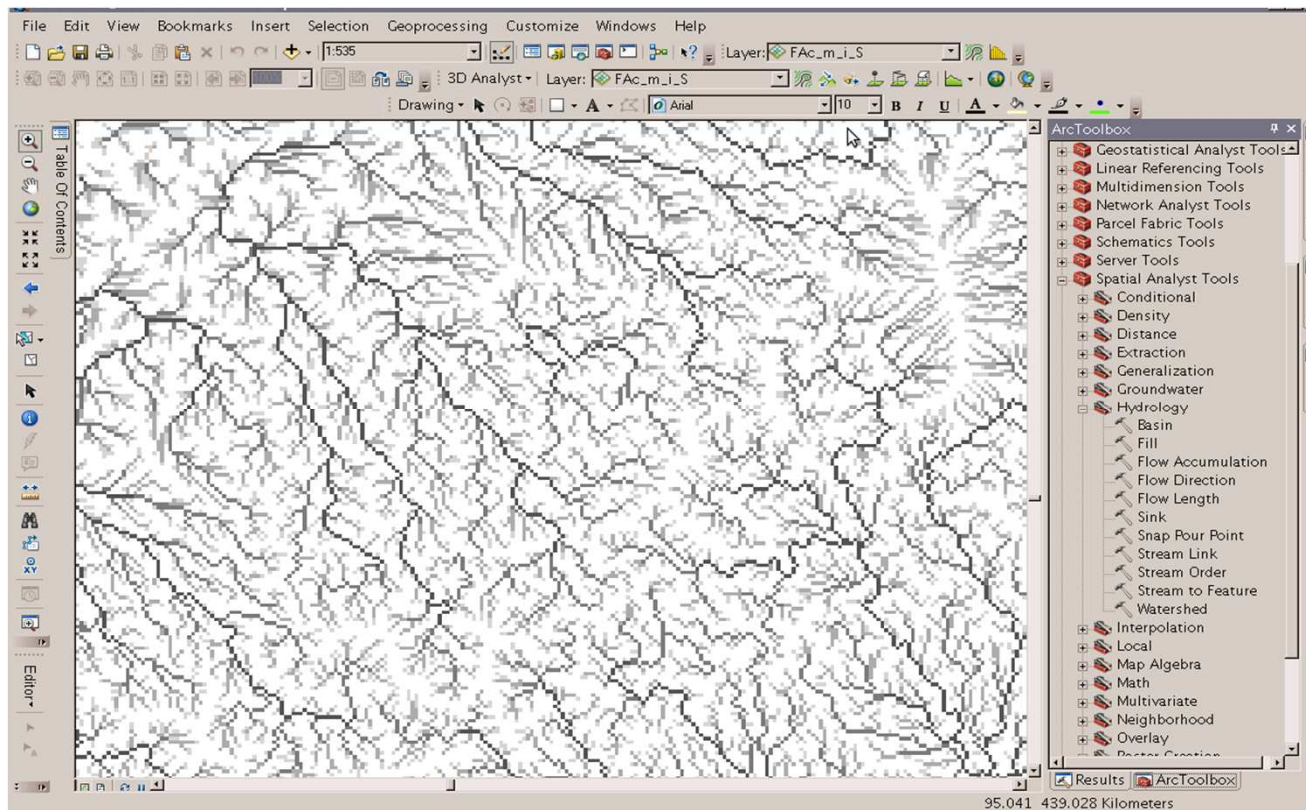
<http://www.dpi.inpe.br/spring/english/index.html>



# Spatial processing and analysis software

**ArcGIS, ESRI – USA**

<http://www.esri.com/software/arcgis/index.html>



Key extensions for ArcMap:

- **3D Analyst** for kriging
- **Spatial Analyst** for  
Hydrological analysis  
(flow direction, flow  
accumulation, streamlines  
and watersheds  
extraction)

# Conceptual model

## Water content in soil:

$$W = W0 + R + C - I - Ro - Per - Evt$$

W: Soil water content (useful for plant development)

W0: Precedent soil water content

R: Rainfall

C: Phreatic contribution

I: Interception

RO: Run off

Per: Percolation

Evt: Evapotranspiration



# Implementing conceptual model given available data

**GIS-based model for qualitative assessment of the potential soil moisture (for every pixel):**

$$M_p = a(R) + b(Ac) + c(Wt) + d(D) + e(Cn)$$

$M_p$ : Potential moisture in soil

$R$ : Scaled value of the monthly cumulative rainfall

$Ac$ : Scaled value of the flow accumulation (drained area to each pixel)

$Wt$ : Scaled value of the water table level

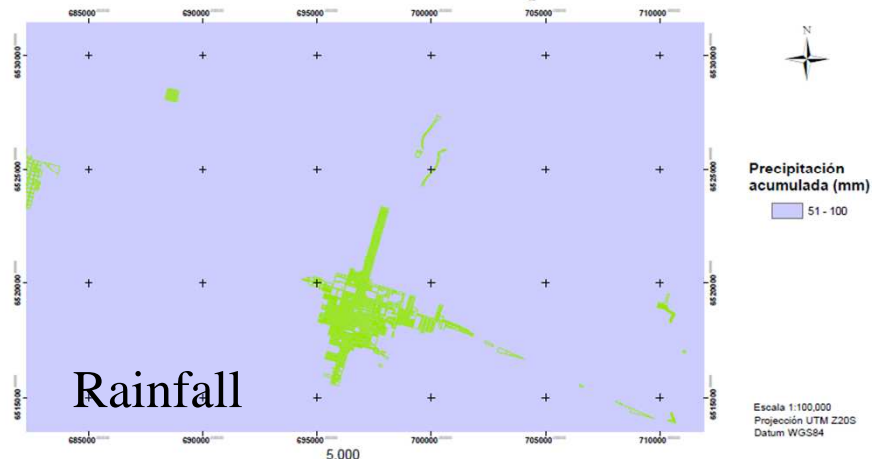
$D$ : Scaled value of the terrain declivity

$Cn$ : Scaled value of the curve number (measure of imperviousness)

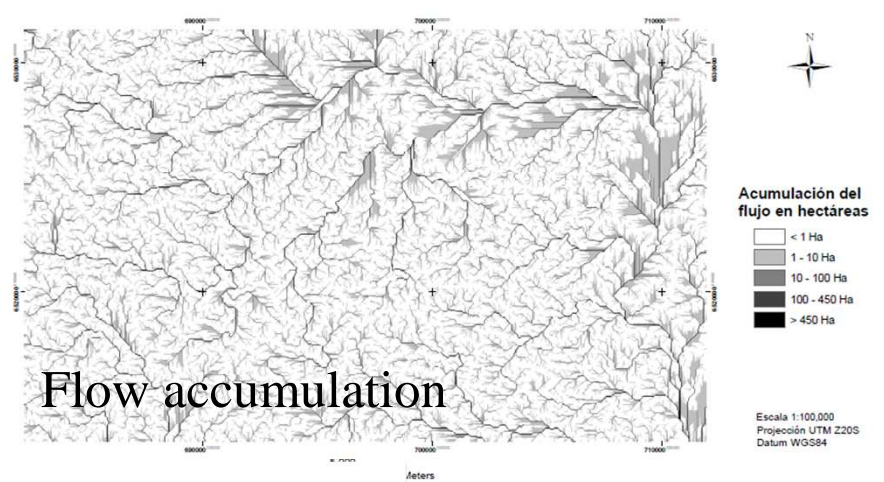
$a, b, c, d$  and  $e$ : weighting parameters (future calibration parameters after verification of the model)

# Model parameters

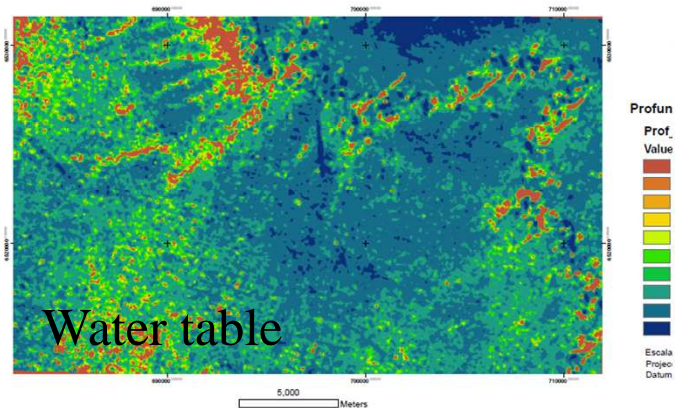
Rango de precipitación acumulada en julio de 2009 en el área Humboldt - Esperanza



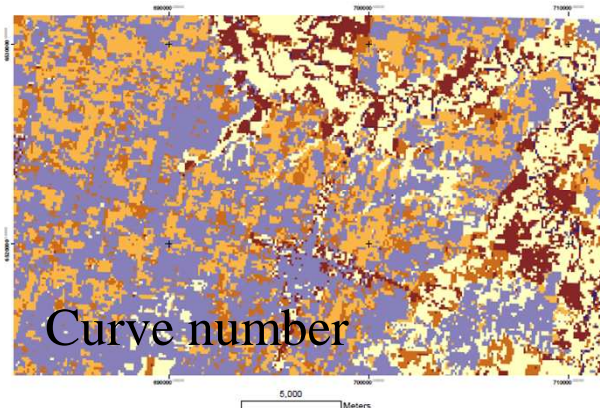
Acumulación del flujo en el área Humboldt - Esperanza



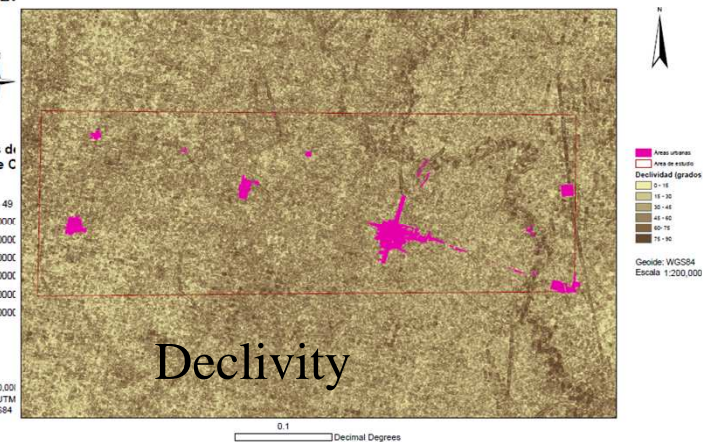
Profundidad freática (cm) en el área Humboldt - Esperanza



Parámetro del Número de Curva en el área Humboldt - Esperanza



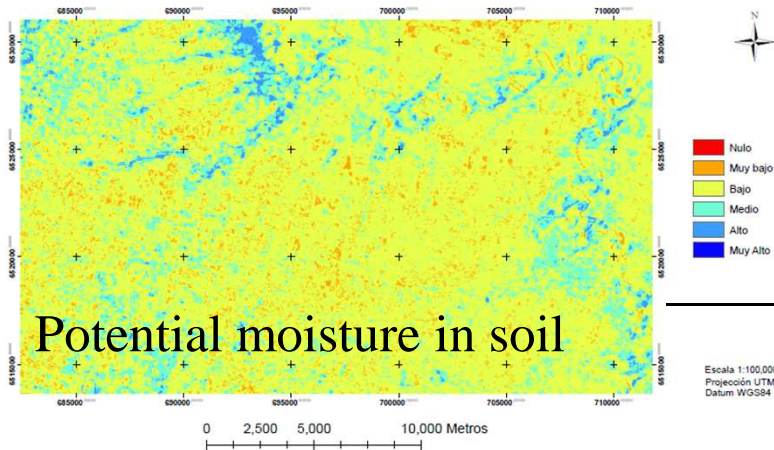
Modelo de declividad en el área de estudio



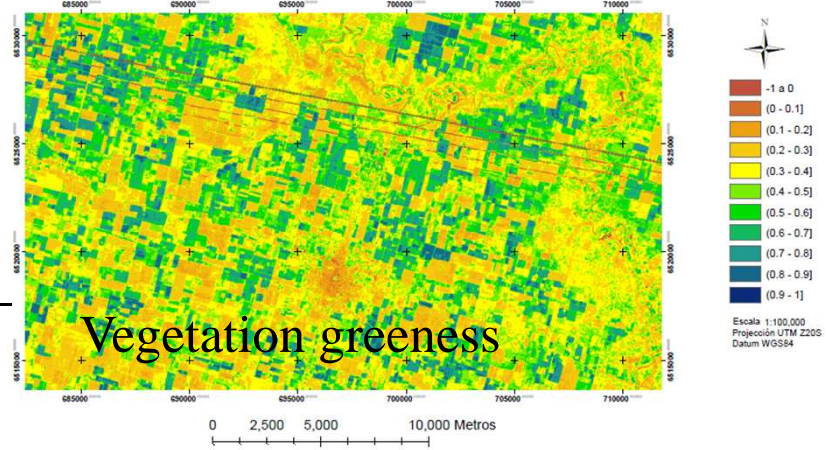


# Results (2/2)

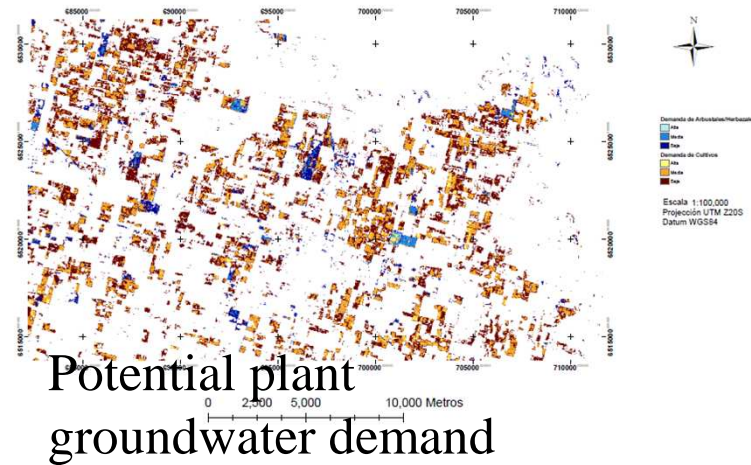
Potencial de Humedad en el área  
Humboldt Esperanza en julio de 2009



Índice de Vegetación de Diferencia Normalizada en el área  
Humboldt Esperanza en julio de 2009

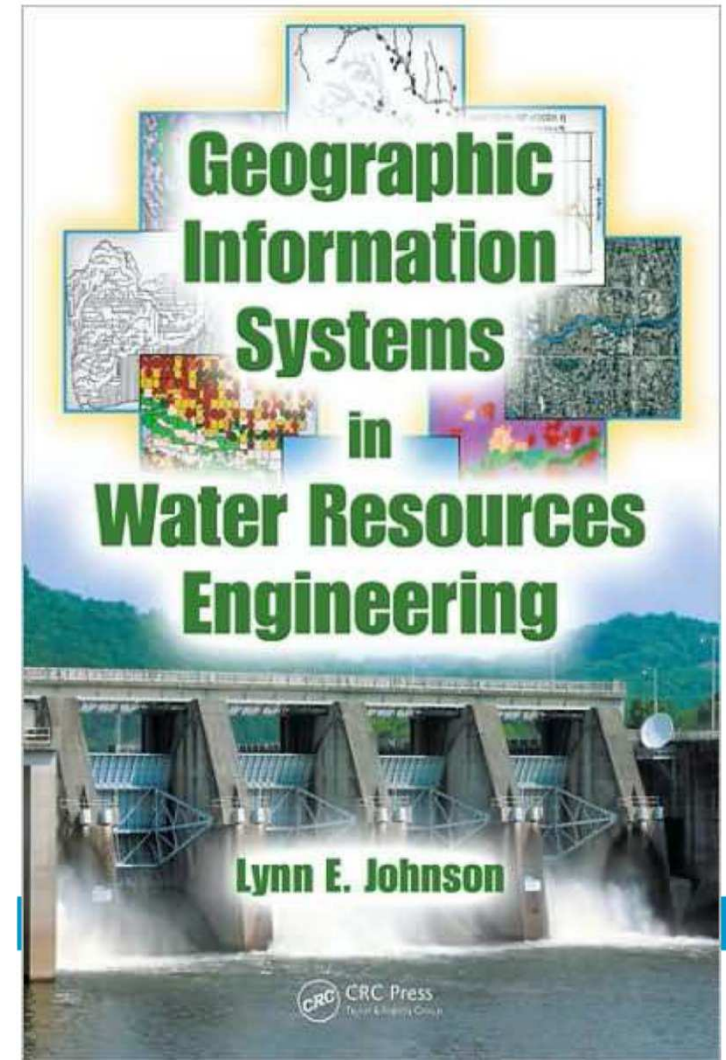


Calificación de la demanda vegetal de agua subterránea  
en el área Humboldt - Esperanza en julio de 2009



# More applications in Hydrology and Water Resources Management

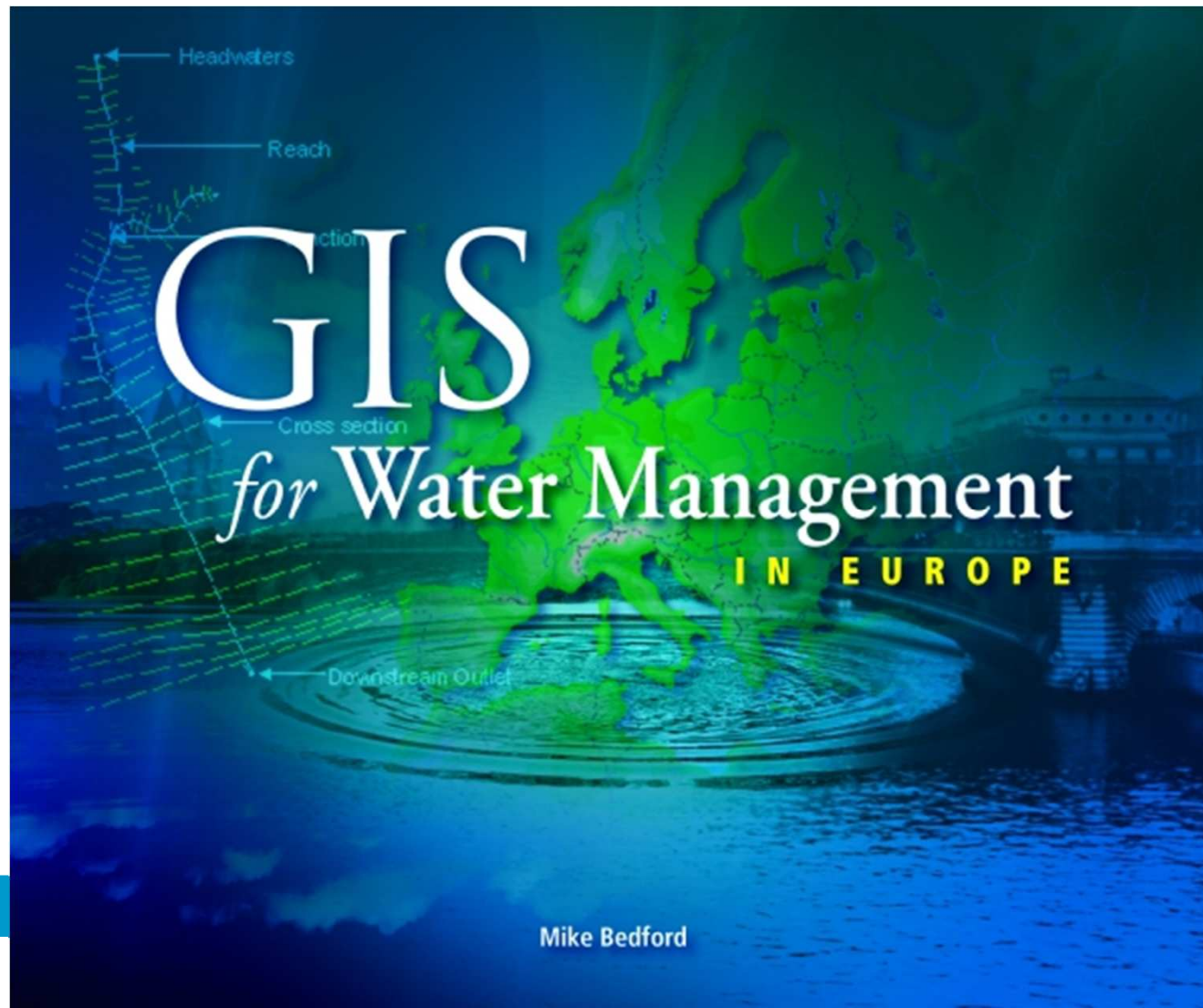
Available online through TU Delft library:





# ESRI

## GIS for Water Management



# Introduction to Assignment 1

**Part 1 Getting started with GIS**

**Part 2 Spatial Analyst toolbox**

**Part 3 How one plus one equals three!**

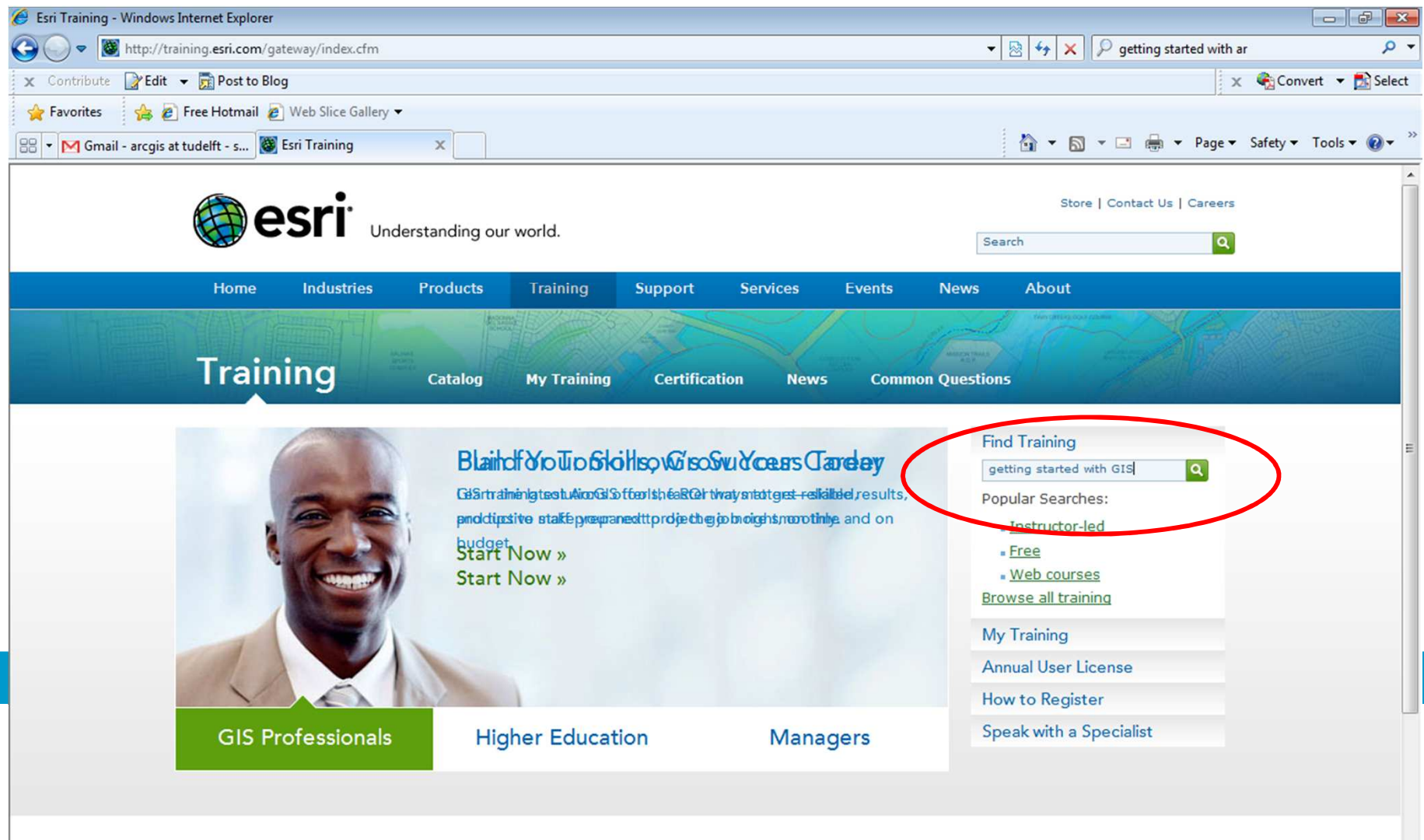
You can bring headphones to listen to audio component of slideshow.

It might be useful to bring laptop to have instructions on one screen while you do ArcMap bits on desktop.

# Assignment 1

## Part 1, Getting started with GIS

- Go to **training.esri.com**
- Under Find Training, enter "Getting Started with GIS"



Select  
the  
**FREE**  
web  
course!

Esri Training - Windows Internet Explorer

http://training.esri.com/gateway/index.cfm?fa=search.results&searchterm=getting+started+with+GIS

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Showing 1 to 9 of 9 results. [New search](#)

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<a href="#">ArcGIS Desktop I: Getting Started with GIS (10.0)</a> <a href="#">Show Overview</a>	<b>Format:</b> Instructor-Led <b>Duration:</b> 2 days (16 hours) <b>Price:</b> \$1,010 USD <b>ArcGIS Version:</b> 10.0 <a href="#">View Class Schedule</a>
<a href="#">Getting Started with GIS (for ArcGIS 10)</a> <a href="#">Show Overview</a>	<b>Format:</b> Web Course <b>Duration:</b> 3 modules (9 hours) <b>Price:</b> Free <b>ArcGIS Version:</b> 10.0
<a href="#">Mobile GIS: Getting Started with the ArcGIS API for iOS</a> <a href="#">Show Overview</a>	<b>Format:</b> Web Course <b>Duration:</b> 1 module (3 hours) <b>Price:</b> \$32 USD
<a href="#">ArcGIS I: Introduction to GIS</a> <a href="#">Show Overview</a>	<b>Format:</b> Instructor-Led <b>Duration:</b> 2 days (16 hours) <b>Price:</b> \$1,010 USD <b>ArcGIS Version:</b> 10.1 <a href="#">View Class Schedule</a>

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## Getting Started with GIS (for ArcGIS 10)

Format: [Web Course](#)

Duration: 3 modules (9 hours)

Price: Free

ArcGIS Version: 10.0

Authored by Esri

New Catalog Search

This is a Free Course

[Go to Course](#)

Overview

Software Requirements

Course Outline

Prerequisites



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E-mail



Bookmark

### Description

This course provides a foundation for understanding what a geographic information system is and the possibilities it offers for discovering patterns, relationships, and trends. You will learn how GIS maps are different from other types of paper and digital maps, what makes the data used in a GIS unique, and how to use GIS software to obtain information and create meaningful maps. In interactive exercises and activities throughout the course, you will work with ArcGIS software and see how a GIS supports problem solving in many different contexts.

### Who Should Attend

Individuals with no GIS background or experience who want to learn the basic features of a GIS and a geographic approach to solving problems.

### Goals

After completing this course, you will be able to

- Explain what a GIS is.
- List some ways that GIS is being used to address real-world problems.
- Display geographic data on a GIS map.
- Query a GIS database to gain information and locate features.
- Understand different types of spatial relationships among real-world features.
- Use analysis tools to create new data.
- Apply a standard approach to solving geographic problems.

### Questions?

[Contact us via e-mail](#) or call toll-free at 888-377-4575, select option 3, between 8:00 AM and 5:00 PM (Pacific Time).

“ I enjoyed taking this on-line and going at my own pace. The simulations were good and the exercises were excellent. Great course!! ”

Cynthia Porter-Johnson,  
Virginia

Esri Training - Windows Internet Explorer

http://training.esri.com/gateway/index.cfm?fa=login.loginForm&rtOverride=http%3A%2F%2Ftraining%2Eesri%2Ecom%2FCourses%2FStartGIS%2F

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http://training.esri.com/Courses/StartGIS\_10/index.cfm

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## Getting Started with GIS (for ArcGIS 10)

by Esri

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- Course Introduction
- Before You Start
- Course Data
- Module 1: The Big Picture of GIS
- Module 2: Understanding Geography
- Module 3: Analyzing Geographic Data
- Course Exam
- What's Next
- Course Evaluation

### Course Introduction

« Previous | Next »

Maybe you have heard the term "GIS" and wondered, *What is GIS? Who uses it?* This course answers those questions and addresses the big picture of GIS. You are about to learn what GIS is, how it differs from other mapping systems, and much more. You will explore GIS maps, use different tools to get information from a GIS, and learn a process for using GIS to solve problems.

Through software simulations and hands-on exercises, you will practice working with ESRI's ArcGIS® software. Through a variety of learning activities, you will have the opportunity to participate actively in your own learning.

When you complete this course, you can expect to have a good foundation in GIS concepts as well as some familiarity with ArcGIS software. Note that while you will work with ArcGIS software, this course does not focus on software, but instead aims to give you a solid conceptual foundation to increase your understanding of GIS. We hope you enjoy the experience.

[View the course orientation](#)

« Previous | Next »

Getting Started with GIS (for ArcGIS 10)

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Once you've logged in, you can start the course.

Start> all programs> engineering> arcgis> arcmap

Done Internet | Protected Mode: On 100% 10:30



# Assignment 1, Part 2: Spatial Analyst Tutorial

help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//00nt00000002000000.htm

ArcGIS Resource Center Help Blogs Forums

Desktop 10

- Network Analyst
- Production Mapping
- Roads and Highways Solution
- Schematics
- Spatial Analyst
  - What is the Spatial Analyst extension?
  - Essential Spatial Analyst vocabulary
  - A quick tour of Spatial Analyst
  - Getting started with Spatial Analyst
  - Modeling and solving spatial problems
  - Performing analysis in Spatial Analyst
  - Image classification
  - Map algebra in Spatial Analyst
  - Tutorial
    - About the ArcGIS Spatial Analyst Tutorial
    - Exercise 1: Preparing for an analysis
    - Exercise 2: Accessing Spatial Analyst tools
    - Exercise 3: Finding a site for a new facility
    - Exercise 4: Finding an alternative site
- Task Assistant Manager
- Tracking Analyst
- ArcGIS Server
- Mobile
- Guide books
- Administrator Library
- Copyright information
- License agreement
- ArcGIS Acknowledgments

## About the ArcGIS Spatial Analyst Tutorial

[Resource Center](#) » [Professional Library](#) » [Extensions](#) » [Spatial Analyst](#) » Tutorial

Using the Spatial Analyst tools available with ESRI ArcGIS, you can perform spatial analysis on your data. You can provide answers to simple spatial questions such as How steep is it at this location? and What direction is this location facing? You can also find answers to more complex spatial questions such as Where is the best location for a new facility? and What is the least costly path from A to B? The comprehensive set of Spatial Analyst tools within ArcGIS allows you to explore and analyze your spatial data and enables you to find solutions to your spatial problems. You can run tools from the Spatial Analyst toolbox or the Python Window, accessible via any ArcGIS Desktop application. You can also create your own custom tools (models or scripts) to run a sequence of tools at one time.

[A quick tour of Spatial Analyst](#)

### Tutorial Scenario

The town of Stowe, Vermont, USA, has experienced a substantial increase in population. Demographic data suggests this increase has occurred because of families with children moving to the region, taking advantage of the many recreational facilities located nearby. It has been decided that a new school must be built to take the strain off the existing schools, and as a town planner, you have been assigned the task of finding the potential site.

This tutorial will show you how to use many of the available tools and will give you a solid basis from which you can start to think about how to solve your own specific spatial problems.

It is assumed that you have installed ArcGIS Desktop (ArcView, ArcEditor, or ArcInfo) and the ArcGIS Spatial Analyst extension before you begin this tutorial. If you need more information about extensions, see [Using Extensions in ArcGIS](#).

The data required is included on the ArcGIS Desktop CD. After running the ArcGIS setup, on the **Additional Installation Components** dialog box, check to install the ArcGIS Tutorial Data. On the **ArcGIS Tutorial Data Setup** wizard, check to install the Spatial Analyst data (the default installation path is C:\arcgis\ArcTutor\SpatialAnalyst). The datasets were provided courtesy of the state of Vermont for use in this tutorial. The tutorial scenario is fictitious, and the original data has been adapted for the tutorial.

Dataset	Description
Elevation	Raster dataset representing the elevation of the area
Landuse	Raster dataset representing the land-use types over the area
Roads	Feature class representing the linear road network for the town of Stowe



# Assignment 1, Part 2: Spatial Analyst Tutorial

help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//00nt00000002000000.htm

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- Spatial Analyst
  - What is the Spatial Analyst extension?
  - Essential Spatial Analyst vocabulary
  - A quick tour of Spatial Analyst
  - Getting started with Spatial Analyst
  - Modeling and solving spatial problems
  - Performing analysis in Spatial Analyst
  - Image classification
  - Map algebra in Spatial Analyst
  - Tutorial
    - About the ArcGIS Spatial Analyst tutorial
    - Exercise 1: Preparing for analysis
    - Exercise 2: Accessing Spatial Analyst and Data Exploration
    - Exercise 3: Finding a site for a new school
    - Exercise 4: Finding an alternate access route
- Task Assistant Manager
- Tracking Analyst
- ArcGIS Server
- Mobile
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- Administrator Library
- Copyright information

Landuse	Raster dataset representing the land-use types over the area
Roads	Feature class representing the linear road network for the town of Stowe
Rec_sites	Feature class representing point locations of recreation sites
Schools	Feature class representing point locations of existing schools
Destination	Feature class representing the destination point used when finding the best route for a new road

This tutorial is divided into exercises and is designed to allow you to explore the Spatial Analyst functionality in ArcGIS at your own pace.

- In Exercise 1, you'll prepare for analysis. You'll copy the tutorial data locally and create a geodatabase to hold your results.
- In Exercise 2, you'll learn the location of the Spatial Analyst tools, create a hillshade output, and explore your data.
- In Exercise 3, you'll create a suitability map to help you find the best location for a new school. You'll derive datasets of distance, reclassify datasets to a common scale, then weight those that are more important to consider and combine them to find the best location. You'll then locate the optimal site using the selection tools within ArcMap.
- In Exercise 4, you'll find the least costly route for an alternate access road to the new school site.

You will need approximately 90 minutes of focused time to complete the tutorial. Alternatively, you can perform the exercises in your own time, saving your results along the way when recommended.

**Related Topics**

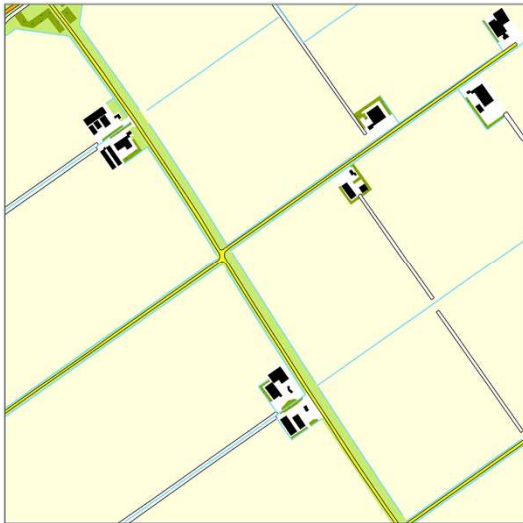
- [Exercise 1: Preparing for analysis](#)
- [Exercise 2: Accessing Spatial Analyst and Data Exploration](#)
- [Exercise 3: Finding a site for a new school](#)
- [Exercise 4: Finding an alternate access route](#)
- [What is the Spatial Analyst extension?](#)

**Do all four exercises**

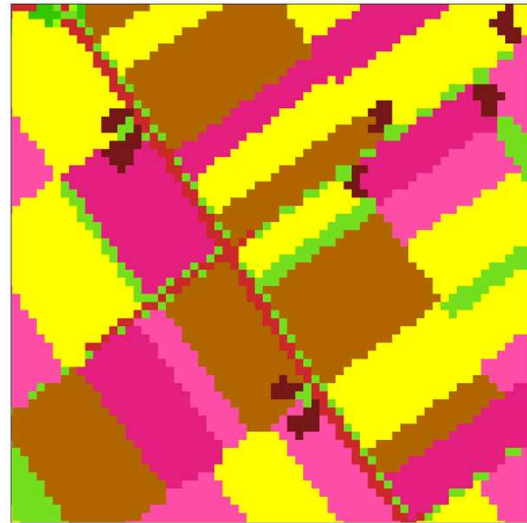
# Assignment 1, Part 3:

## How one plus one equals three

TOP10NL



LGN6



Improved combined map.



# Sources images

If a website or number is not added to a picture, then the image is taken from [www.esri.com](http://www.esri.com).

- [1] Cliparts, source: unknown.
- [2] Grasmere Lake, Cumbria, UK; photo courtesy of Tony Richards.
- [3] Dam of Clywedog reservoir, source: [http://www.euwfd.com/html/lakes\\_and\\_reservoirs.html](http://www.euwfd.com/html/lakes_and_reservoirs.html)
- [4] Multi-angle Imaging SpectroRadiometer (MISR), photo courtesy of NASA.
- [5] GOES-13 satellite, photo courtesy of NASA.
- [6] Satellites measure sea level with unseen signals, photo courtesy of NASA.
- [7] Reference ellipsoid WGS84, source: unknown.