EnvSci 360 Computer and Analytical Cartography
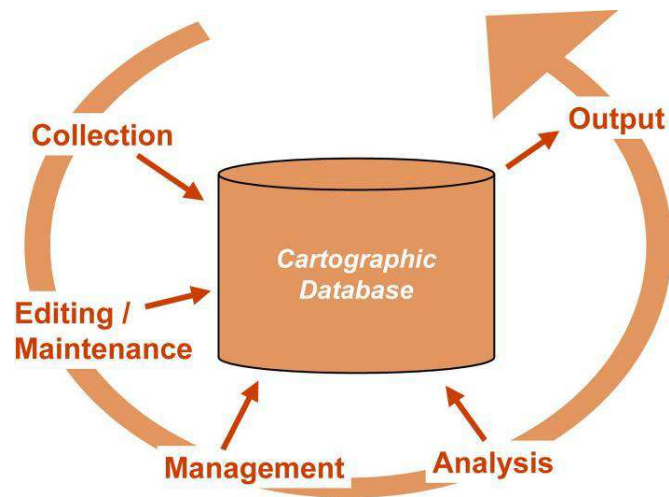
Lecture 1

Course overview

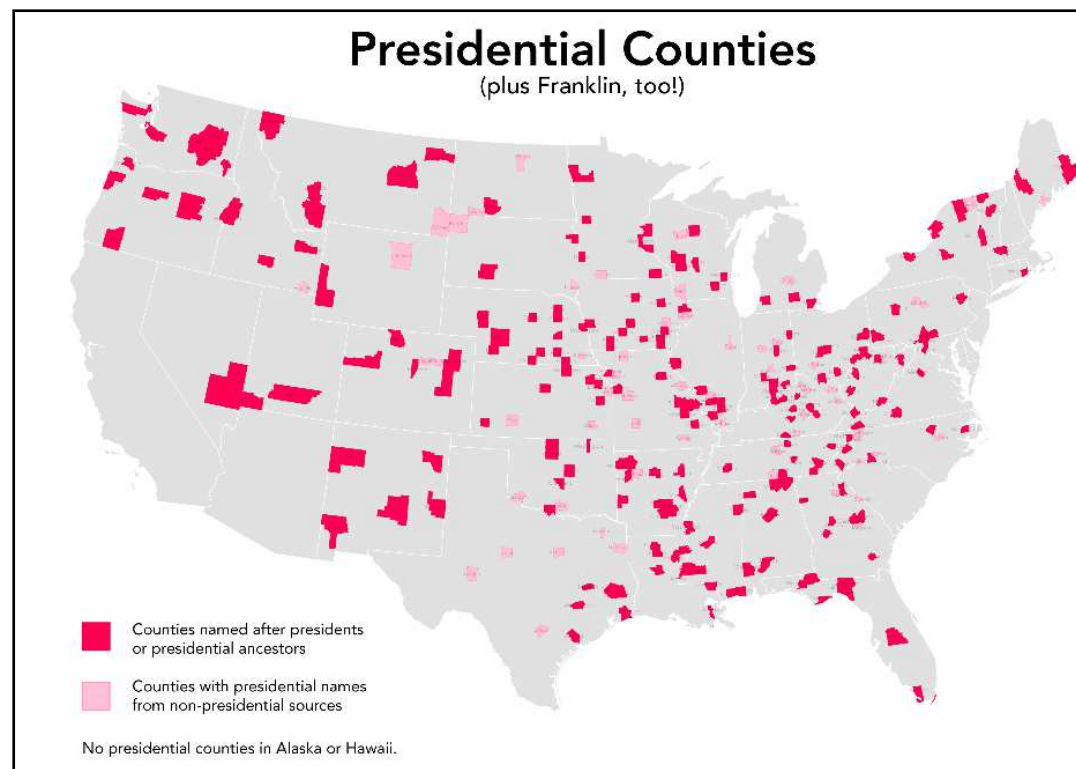*History of cartography*

Basic map design and layout

Course Overview

✳ This course is about what goes into making maps -- good maps -- the most recognizable feature of a GIS (Geographic Information System)
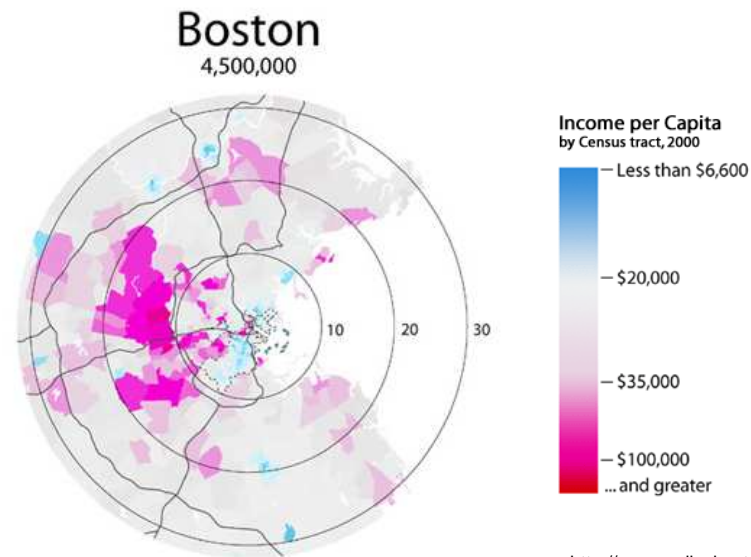
Defining "Cartography"

* *How do you define cartography?*

Presidential Counties
(plus Franklin, too!)

■ Counties named after presidents or presidential ancestors

▨ Counties with presidential names from non-presidential sources

No presidential counties in Alaska or Hawaii.

http://www.radicalcartography.net/index.html?presidential

Defining "Cartography"

✳ *How do you define cartography?*

Number of presidents by place of birth

- 🟦 8
- 🟪 7
- 🟥 5
- 🩷 4
- 🟧 2
- 🟨 1

https://www.yahoo.com/news/map-where-every-us-president-was-born-120535059.html

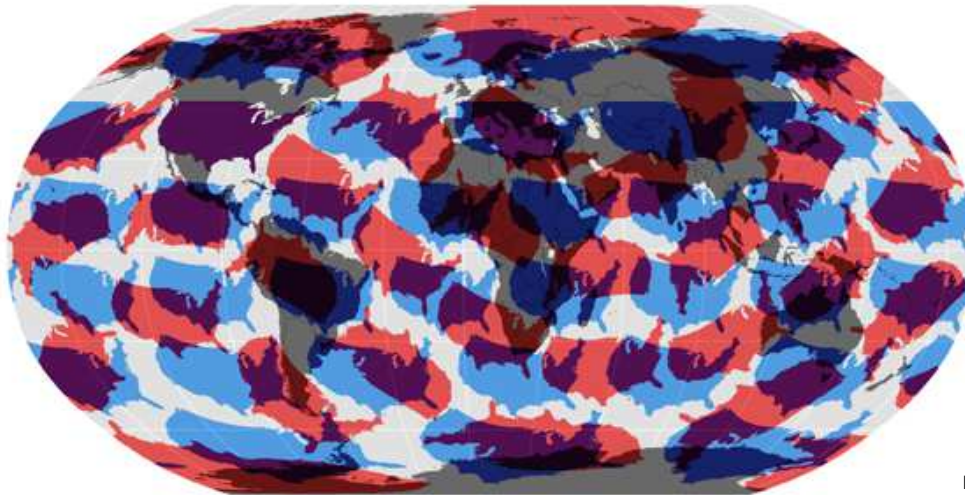Created with mapchart.net ©

Defining "Cartography"

✳ "The making and study of maps in all their aspects" - <u>Elements of Cartography</u>

✳ "The art, science, and technology of making maps" - <u>International Cartographic Association</u>

✳ "The creation, production, and study of maps"
  – <u>http://science.jrank.org/pages/1258/Cartography.html</u>

Boston
4,500,000

Income per Capita
by Census tract, 2000

- Less than $6,600
- $20,000
- $35,000
- $100,000 ...and greater

10 20 30

http://www.radicalcartography.net/index.html?cityincome

Defining "Cartography"

✱ The art and science of expressing graphically, usually through maps, the natural and social features of the earth

- http://support.esri.com/en/knowledgebase/Gisdictionary/term/cartography

✱ "The production of maps, including construction of projections, design, compilation, drafting, and reproduction"
- http://dictionary.reference.com/browse/cartography

✱ In French: carte = map

✱ In Greek: chartis = map and graphein = write

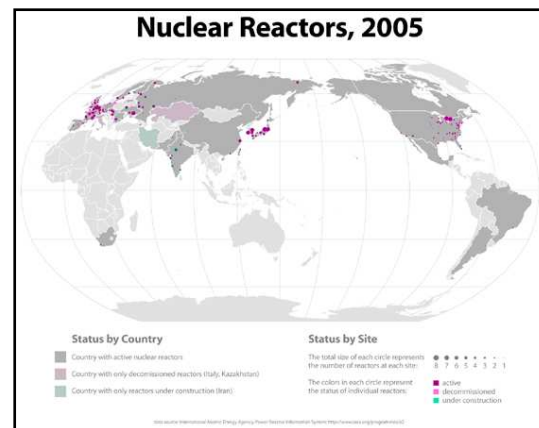http://www.radicalcartography.net/index.html?wandering
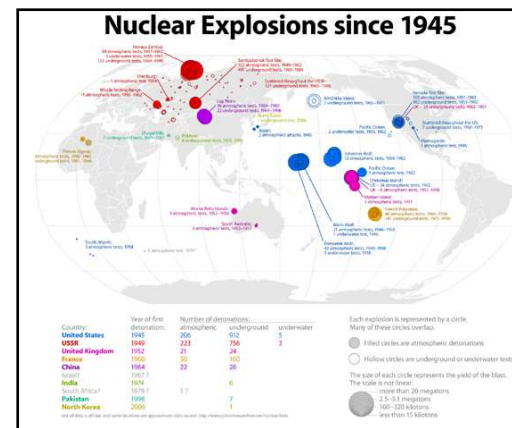
Defining "Map"

✳ *How would you define a map?*

Defining "Map"

✳ "A graphic representation of the spatial relationships of entities within an area"

✳ "Any graphical representation of geographic or spatial information"

✳ "The document used in ArcMap (MXD) to display and work with geographic data. In ArcMap, a map contains one or more layers of geographic data, contained in data frames, and various supporting map elements, such as a scale bar."
 - http://support.esri.com/en/knowledgebase/GISDictionary/term/map

Nuclear Reactors, 2005

http://www.radicalcartography.net/index.html?reactors

Nuclear Explosions since 1945

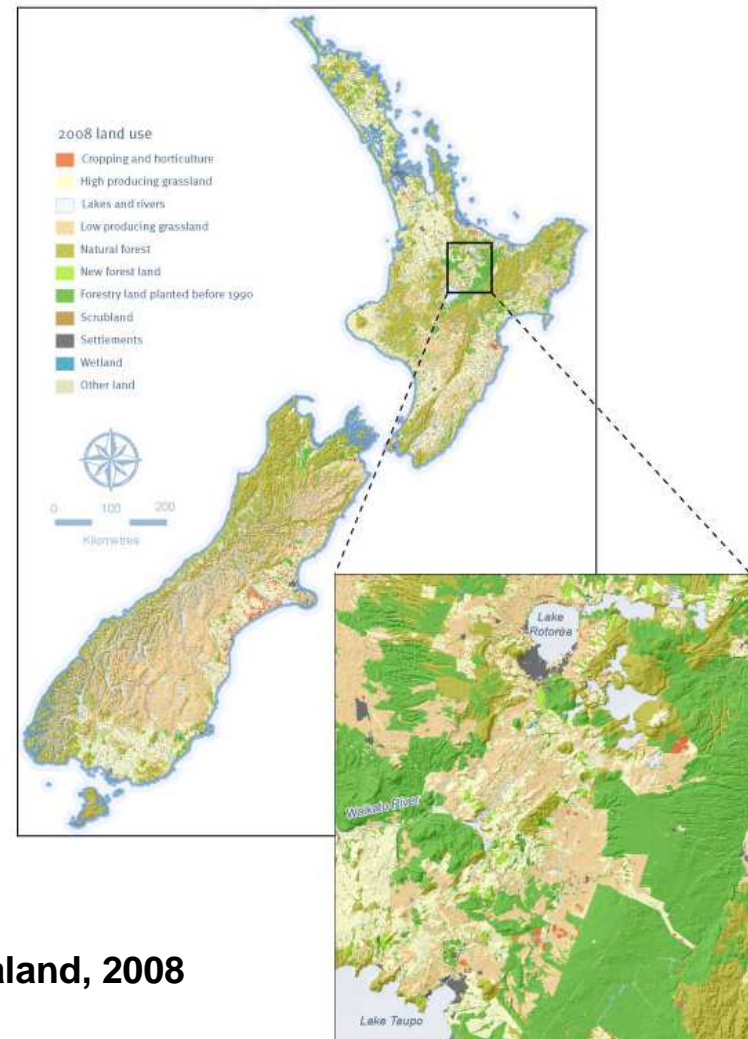http://www.radicalcartography.net/index.html?nuclear

Defining "Map"

✳ "A graphic representation of a geographical setting, communicating information about its cultural and/or physical environment" - <u>Elements of Cartography</u>

✳ "A kind of statement locating facts" – <u>Making Maps 2nd Edition</u>

✳ They are communication vehicles, a type of "visual psychology" using colors and symbols

http://www.radicalcartography.net/index.html?erikamerica
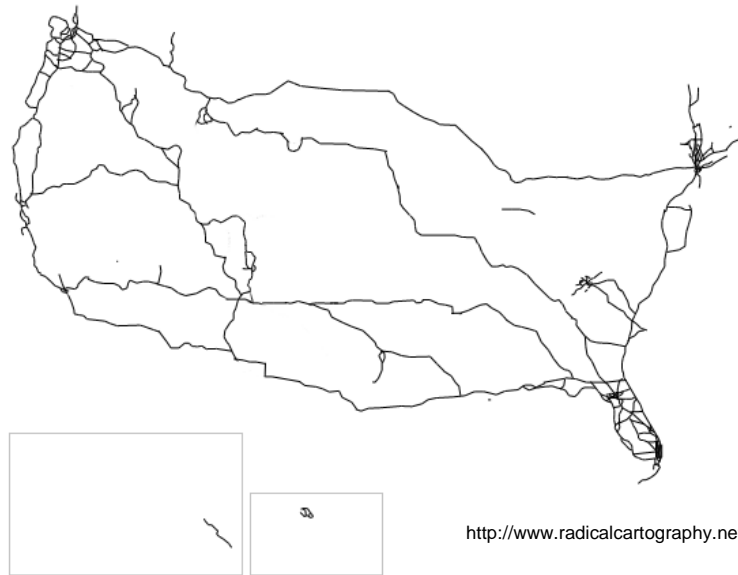
Why Create and Use Maps?

- ✳ Show what features are in that particular place (roads, geology, open space, water resources, etc.) so that someone else - the map user - can understand something about that place
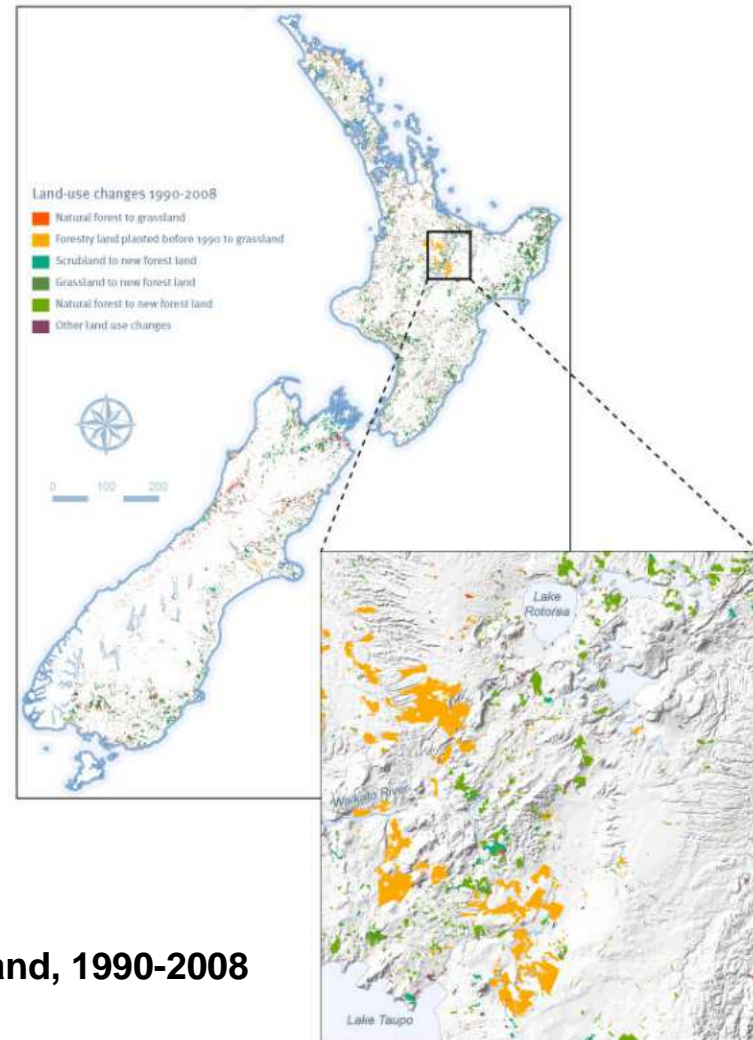

2008 land use
- Cropping and horticulture
- High producing grassland
- Lakes and rivers
- Low producing grassland
- Natural forest
- New forest land
- Forestry land planted before 1990
- Scrubland
- Settlements
- Wetland
- Other land

Land use in New Zealand, 2008

Why Create and Use Maps?

✳ Show change over time
(temporal change)

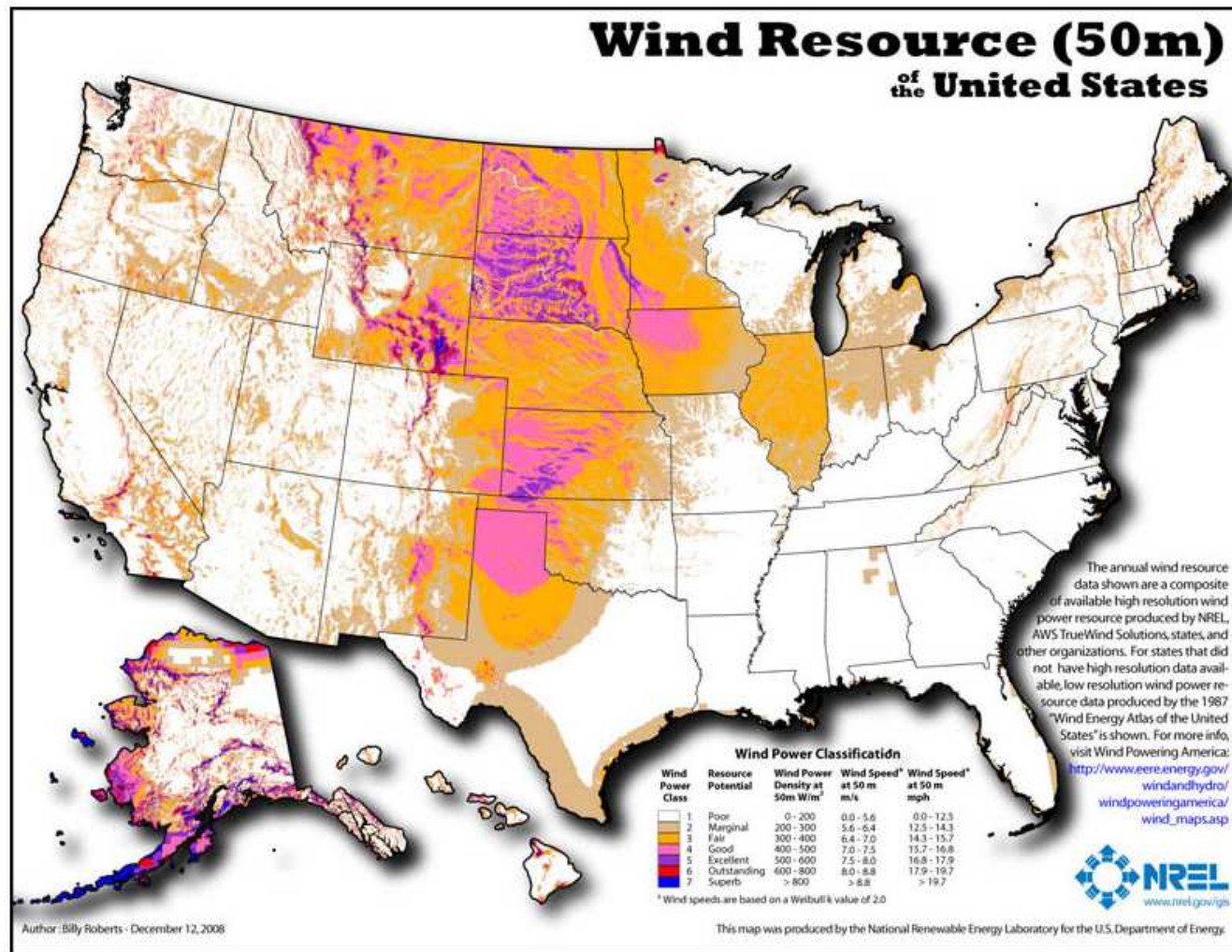**Land use change in New Zealand, 1990-2008**

Why Create and Use Maps?

- Communicate spatial relationships and forms among different aspects and features in an area, and how they depend on each other
  - Distances, patterns, adjacency, distribution…

Per Capita Energy Consumption and CO2 Emission

1 inch on map = 37.80 map units

0.00   50.00   100.00   150.00   200.00
Scale in Map Units
Parallel True to Scale: -20.60

Per Capita Energy Consumption

Per Capita CO2 Emission

Units: Metric Tons

No data
0 to 0.40
0.40 to 0.70
0.70 to 1.48
1.48 to 2.86
2.86 to 13.11

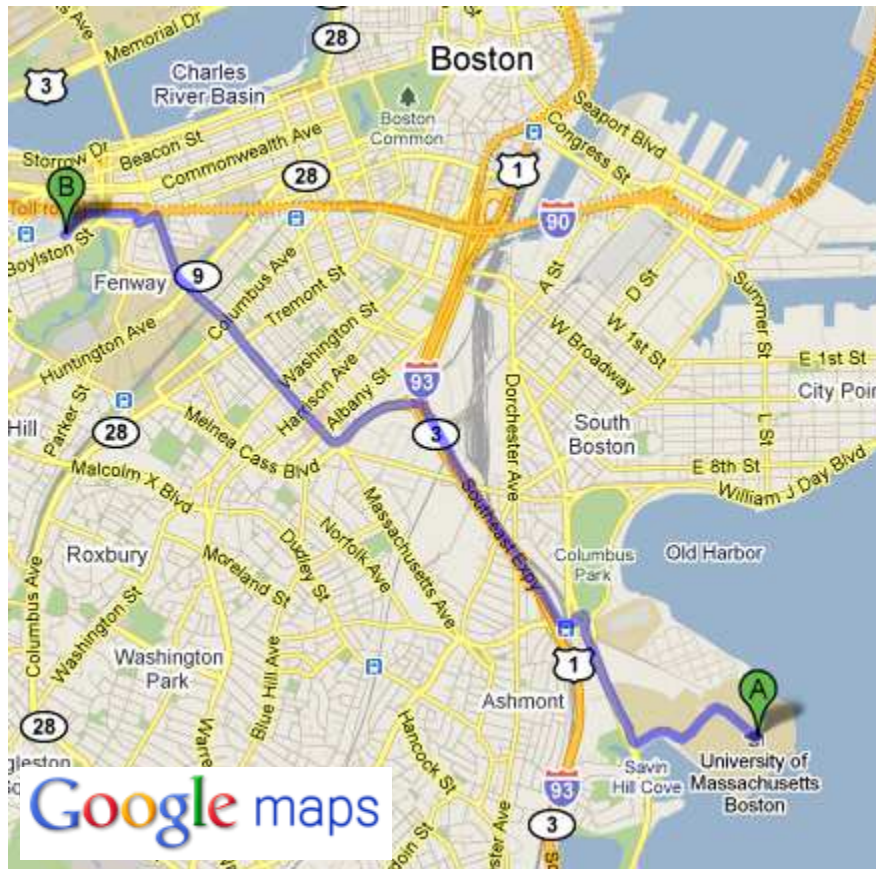2002 oil consumption per capita in tons
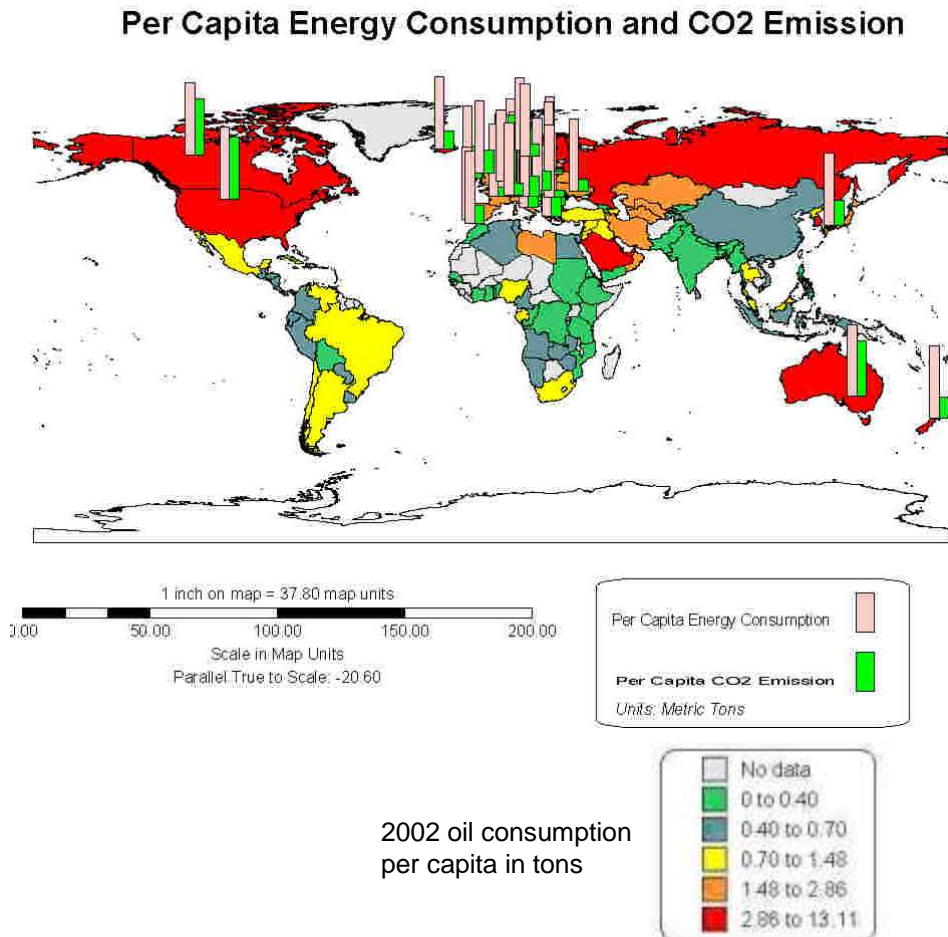
Why Create and Use Maps?

Why Create and Use Maps?
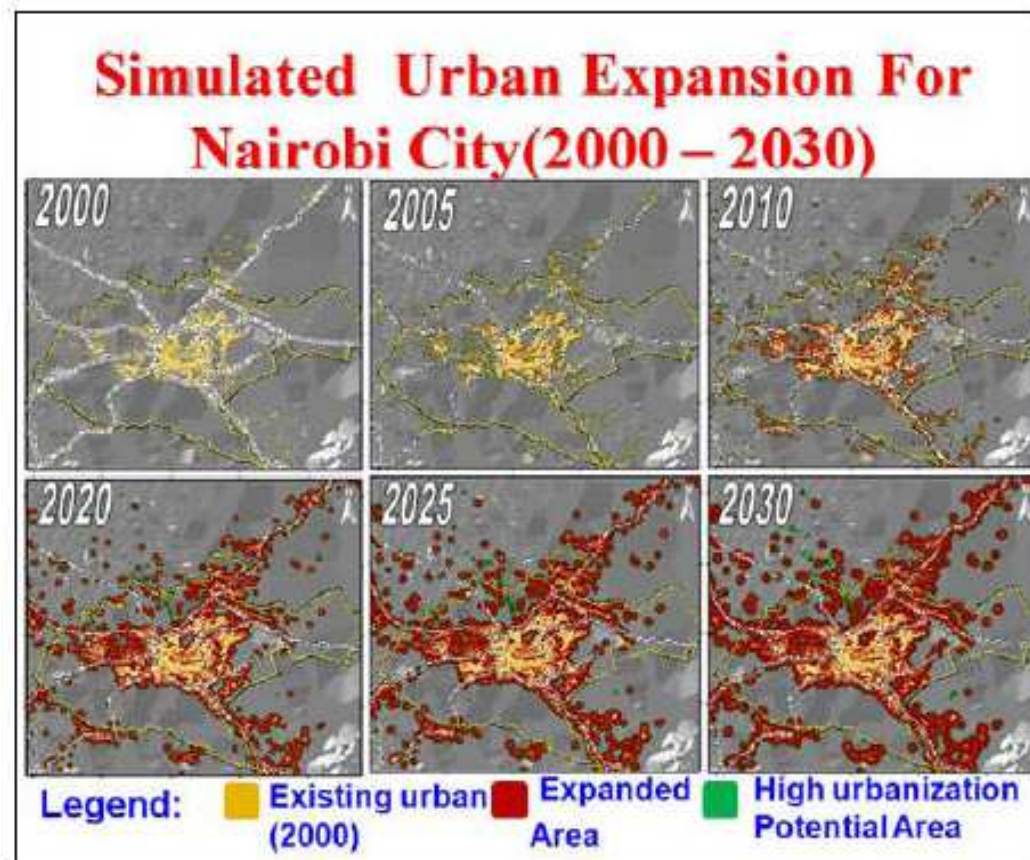
✳ To help you get somewhere

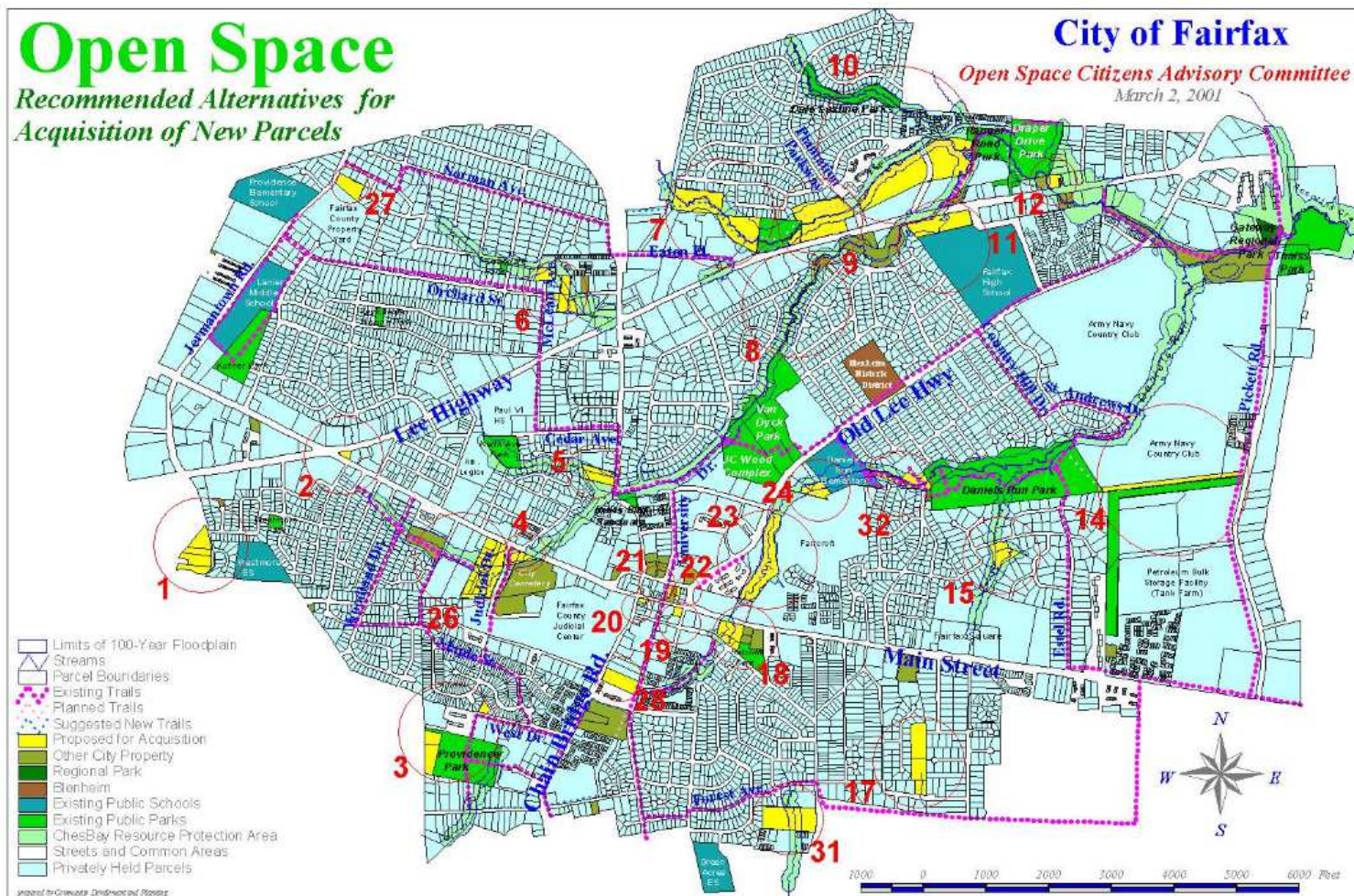**Driving directions from UMass Boston to Fenway Park**

1. Head northwest on University Dr N toward Bianculli Blvd 0.4 mi
2. At the traffic circle, take the 1st exit onto Bianculli Blvd 0.2 mi
3. Turn right at William T Morrissey Blvd 0.6 mi
4. At the traffic circle, take the 2nd exit onto Columbia Rd 0.2 mi
5. Merge onto I-93 N/US-1 N via the ramp to Boston 0.8 mi
6. Take exit 18 for Frontage Rd toward Mass Ave/Roxbury 17 ft
7. Merge onto I-93 Frontage Rd 0.3 mi
8. Turn left at Mass Ave Connector 0.4 mi
9. Take the 1st right onto Massachusetts Ave 1.3 mi
10. Turn left at Boylston St 430 ft
11. Take the 1st right onto Ipswich St 0.4 mi

Why Create and Use Maps?

* As a planning aid - "what-if" scenarios

Simulated Urban Expansion For Nairobi City (2000 – 2030)

2000 | 2005 | 2010
2020 | 2025 | 2030

Legend: ■ Existing urban (2000) ■ Expanded Area ■ High urbanization Potential Area

Why Create and Use Maps?

Why Create and Use Maps?

* Ultimately – to COMMUNICATE
  - Results of spatial analysis
  - To inform via visualization
  - "A picture's worth a thousand words"…
  - A good map is a powerful means of communication …
  but beware of the mapmaker's agenda

Why Create and Use Maps?

- Does this map do its job?
- Do you like this map?

Who Makes Maps

✳ It is important to understand how to make effective maps, because, due to computer technology, mapmaking is shifting from traditional "cartographers" to everyone.

Who Makes Maps

* Professional cartographers are losing some of the control that they had of the field, and how maps were designed and distributed
* The process of mapmaking is being decentralized
* *Do you make maps?*

Who Makes Maps

✳ Mapping software is becoming cheaper (or free!), faster and easier to use.

✳ With easier access to technology, however, there is a danger that those not trained can make mistakes and mislead map readers.

– You can still make bad maps on a computer, certainly worse than one hand-drawn, if you don't know what you're doing.

"The Golden Age of Baseball"
1903 and 1952
http://billsportsmaps.com/?p=366

[By Bill Turianski 2007]

Who Uses Maps?

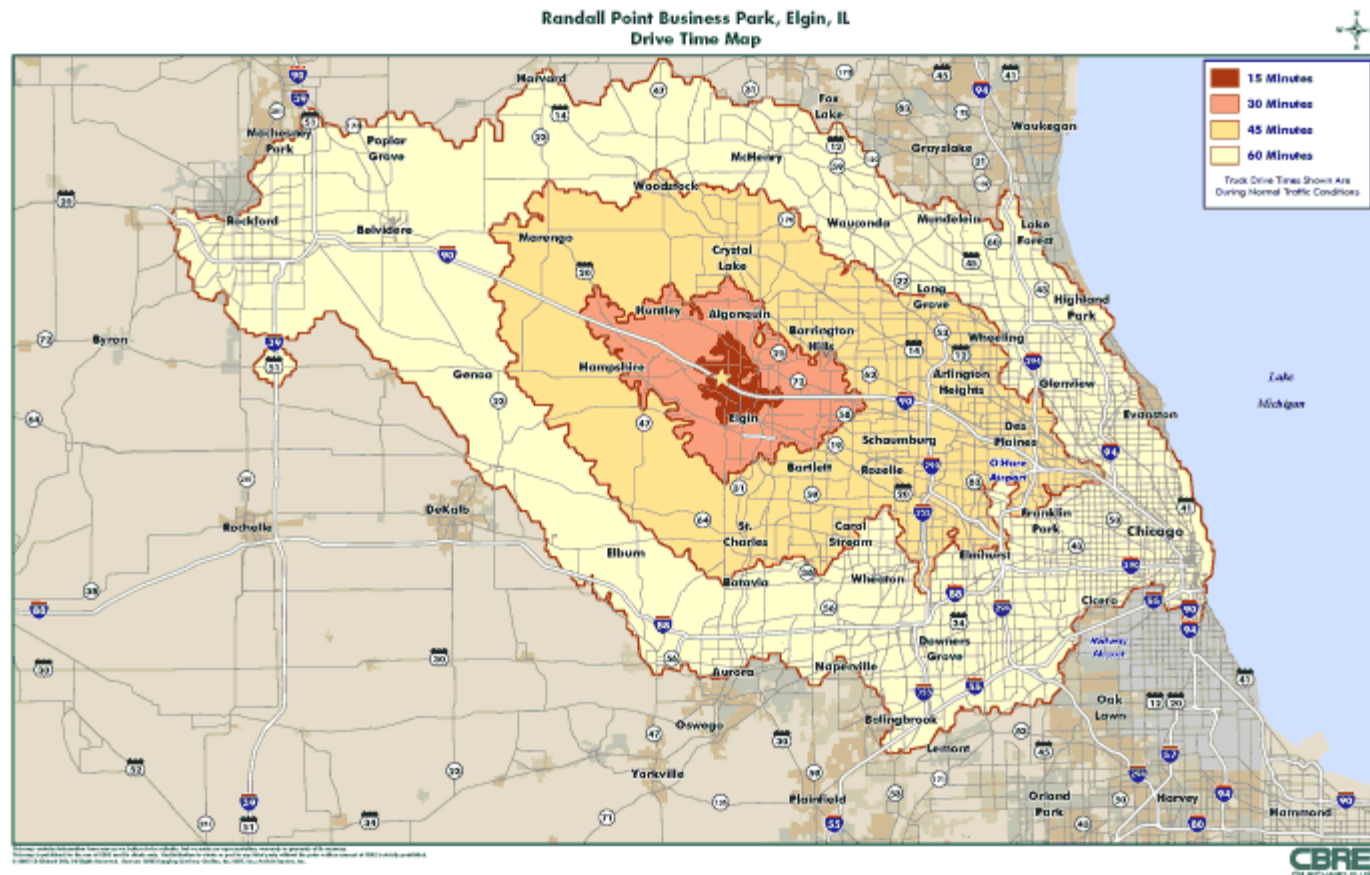✳ Maps are now used by more people in more fields than ever before:

  – **Government, military**

Confirmed military action
in and around Iraq
April 9, 2003
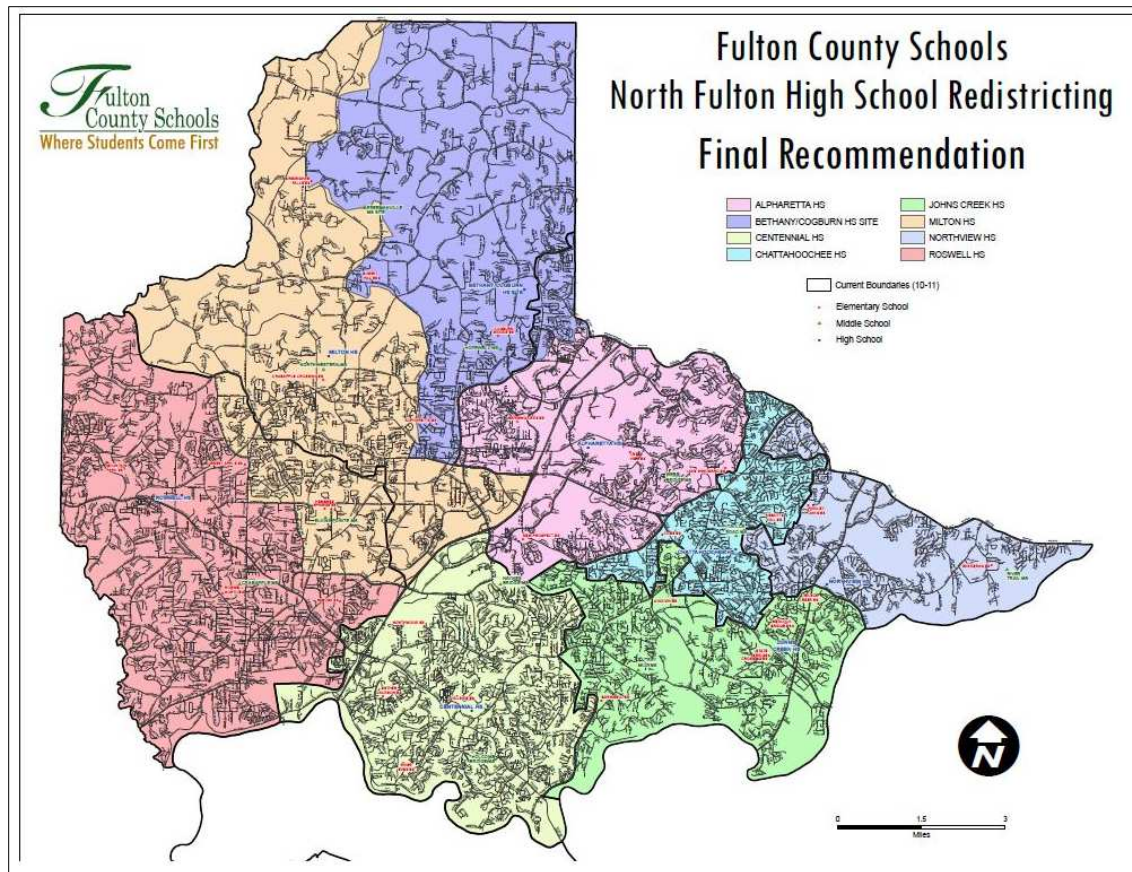http://www.atimes.com/atimes/Middle_East/EC22Ak02.html

○ - Iraq 'red zone' of defense ▮ - Areas believed to be controlled by coalition forces

▨ - Areas controlled by Kurdish forces

Who Uses Maps?

– **Business and industry**

Randall Point Business Park, Elgin, IL
Drive Time Map

Who Uses Maps?

– **Education**

How to Create Maps

* **Paper and ink** (or other hardcopy material)
* **Computer and software** – often (but not always) part of a GIS

Six parts of a GIS

People — Software — Data — Procedures — Hardware — Network

Mapping Conventions

✳ Mapmaking is both an **art and science**

  – Conform to scientific standards and conventions

  • **Colors** (blue water, green forest, etc.)

  • Fit in **supporting elements** around shape of feature (legend, title, scale bar, logos, images, text, etc.)

  • Placement of **labels** (upper-right of points as default; avoid overlapping other features)

  • A bit of white space allows layout to "breathe"

  – But … **be creative**
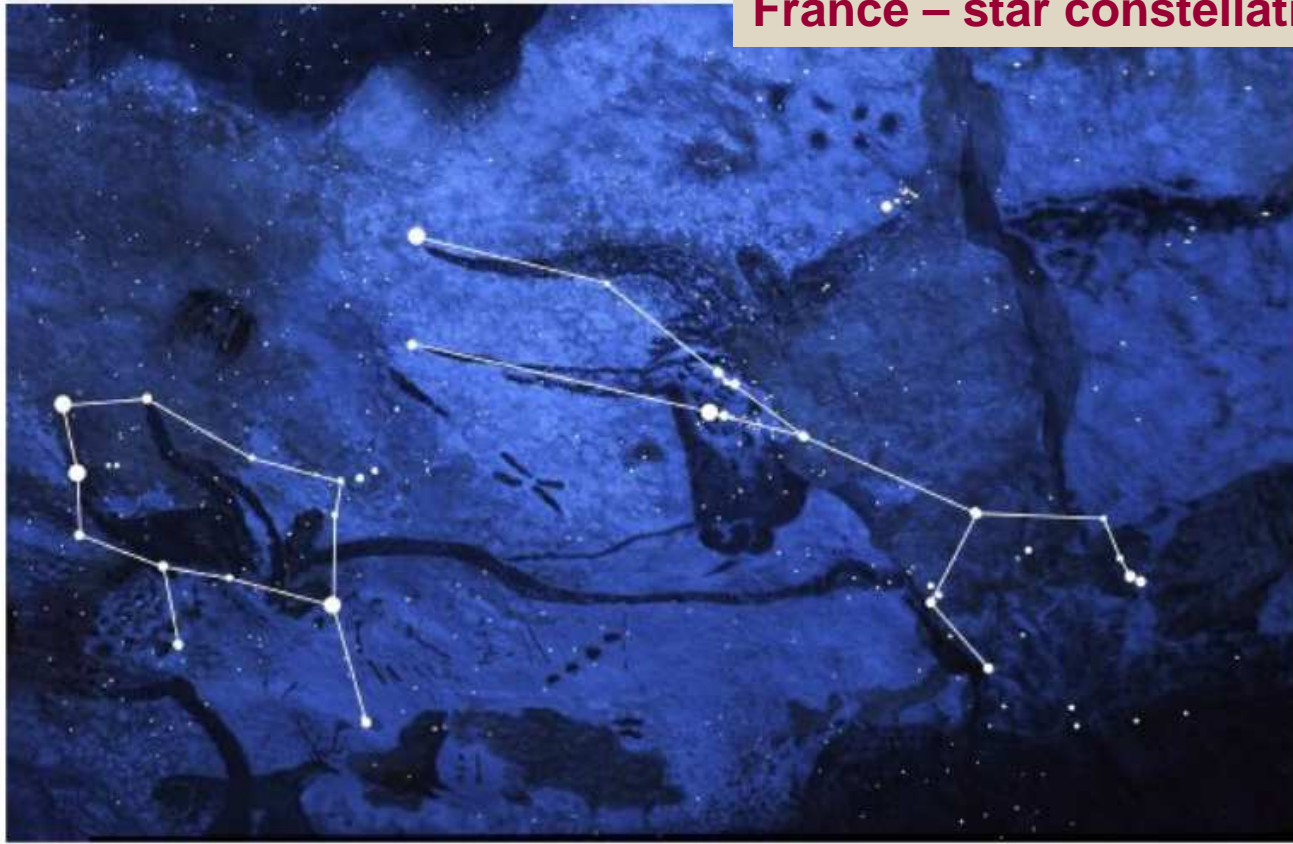
Mapping Conventions??
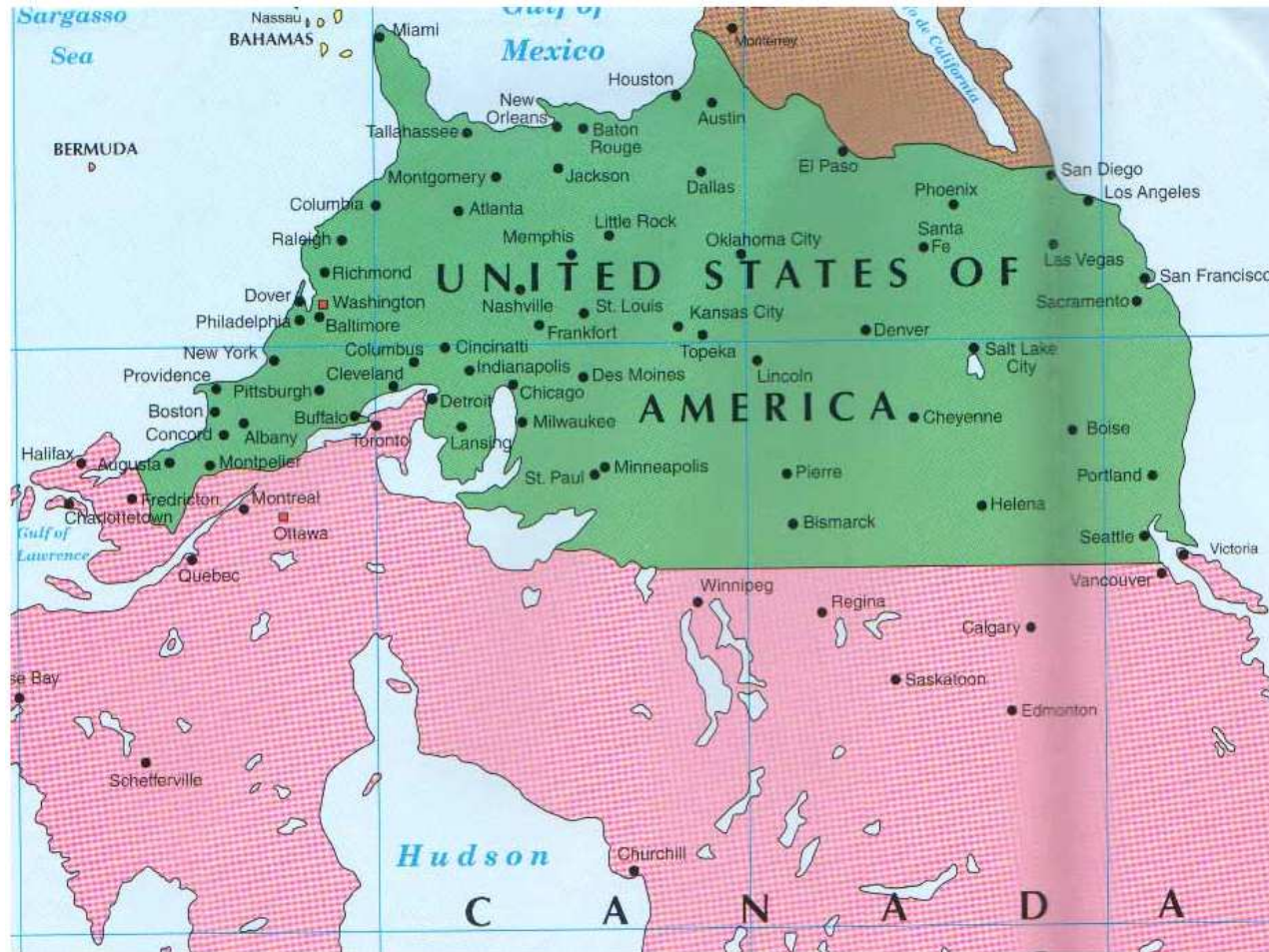
Mapping Conventions??

Limitations of Paper Maps

* Fixed scale

* Fixed extent

* Static view

* Flat and hence limited for 3D visualization

* Appears to present a 'complete' world view

* Map producer-centric

Brief History of Cartography

✳ Earliest maps

17,000 years ago: Lascaux cave paintings, in southwestern France – star constellation maps?

Brief History of Cartography

✳ Earliest maps

14,000 years ago: Cave rock etchings in Spain – area around the cave?

Brief History of Cartography

☀ Earliest maps

River with dwellings along a river, on a mammoth tusk -- 12,000 B.C., Ukraine

Brief History of Cartography

✳ Earliest maps

Babylonian Map of the World -- on a clay tablet, with Babylon at its center, ca. 600 BC. Found in southern Iraq

Brief History of Cartography

✳ Earliest maps

Ptolemy's world map -- the known world to Western society, ca 150, based on the description in his book Geographia. Reconstructed by cartographers when the manuscript was re-discovered around 1300 AD.

Brief History of Cartography

✳ Also see:

- http://www.ancient-wisdom.co.uk/cartography.htm
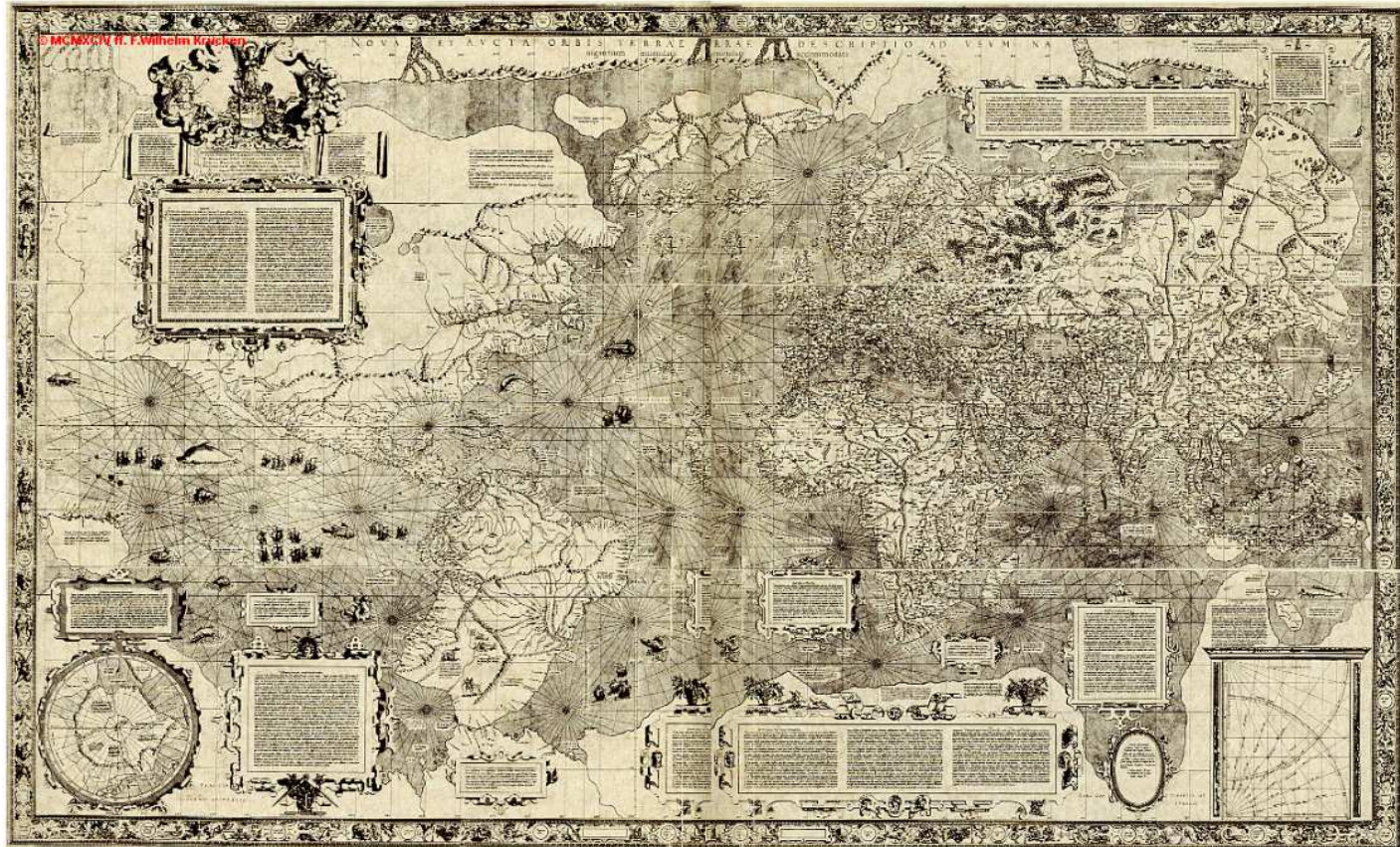- http://academic.emporia.edu/aberjame/map/h_map/h_map.htm

"Hereford mappamundi" (European Medieval map) -- ca 1290 (with East at the top)
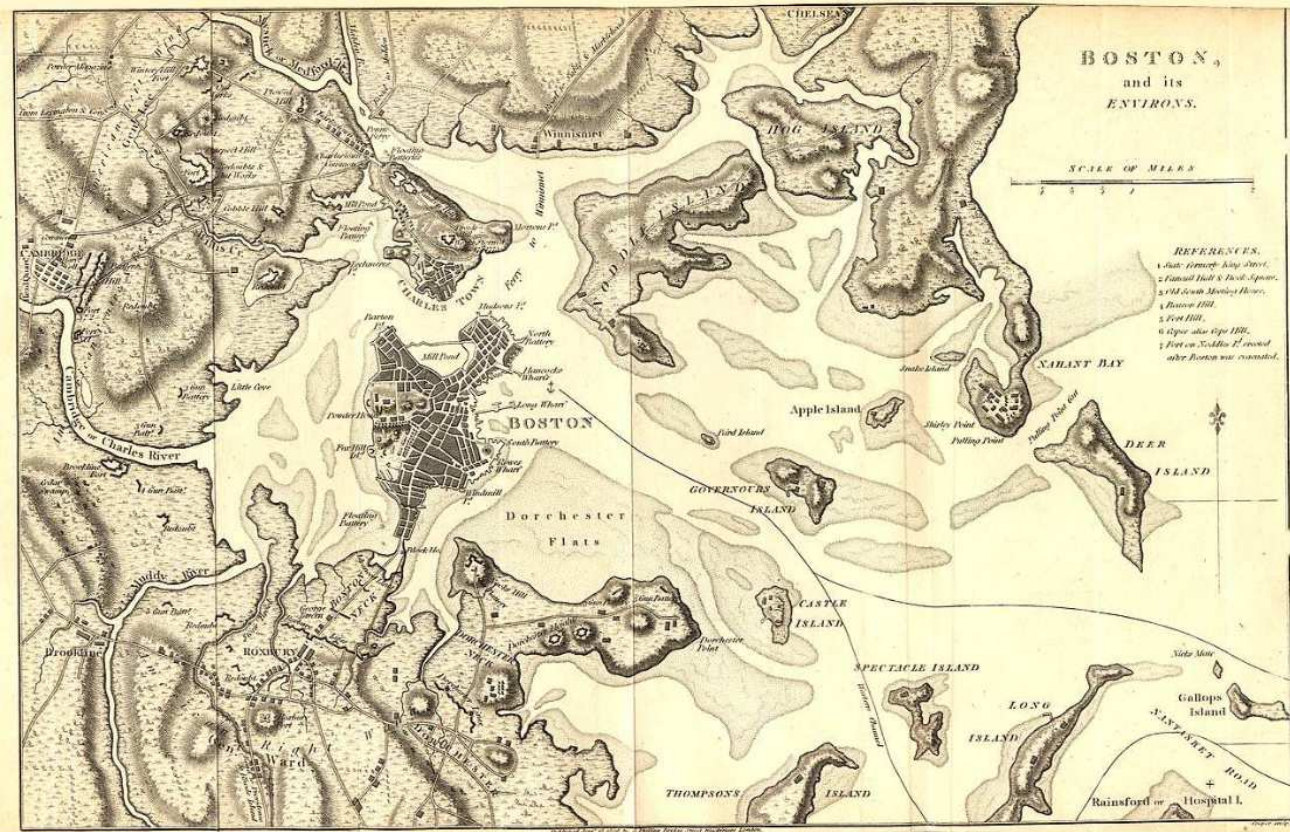
Brief History of Cartography
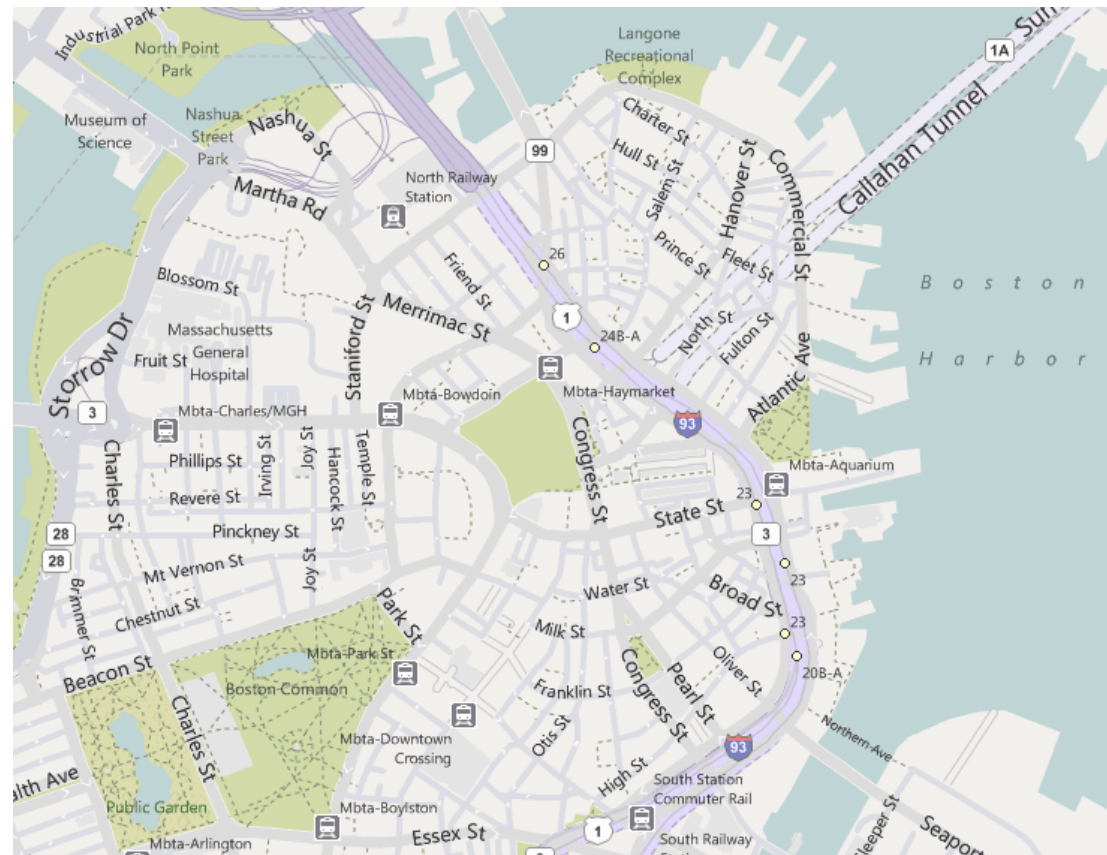
* Renaissance

Mercator's world map, 1569.

Brief History of Cartography

✳ Boston - 1722

Brief History of Cartography

✳ Boston – ca. 1806

Brief History of Cartography
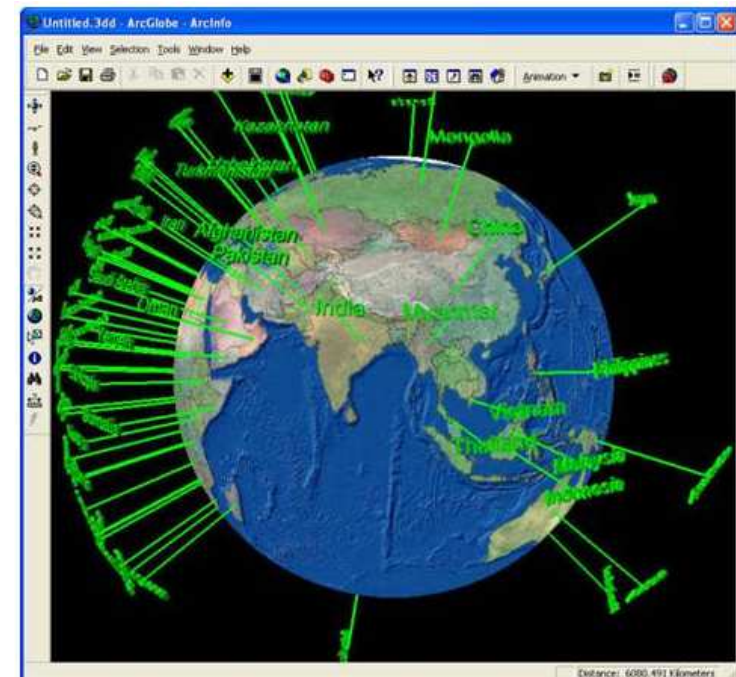
✳ Boston – 2010 (from bing.com)

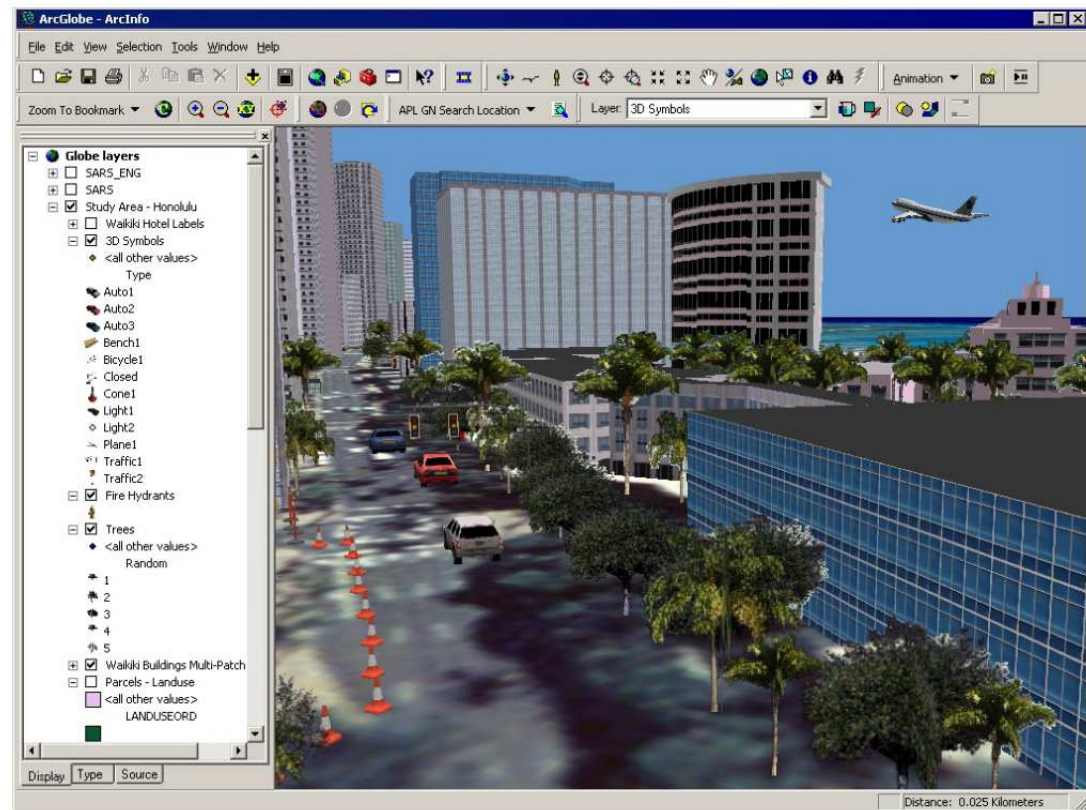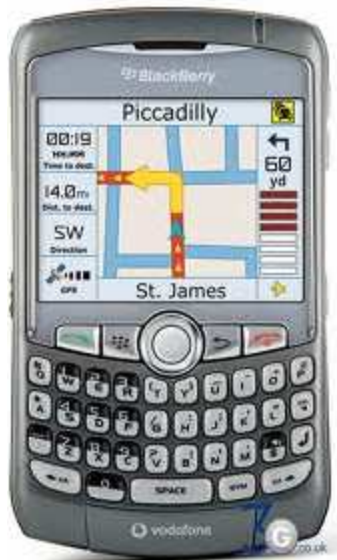# *Brief History of Cartography*

✳ Boston – 2010 (from bing.com)

Brief History of Cartography

✳ Now -- GIS

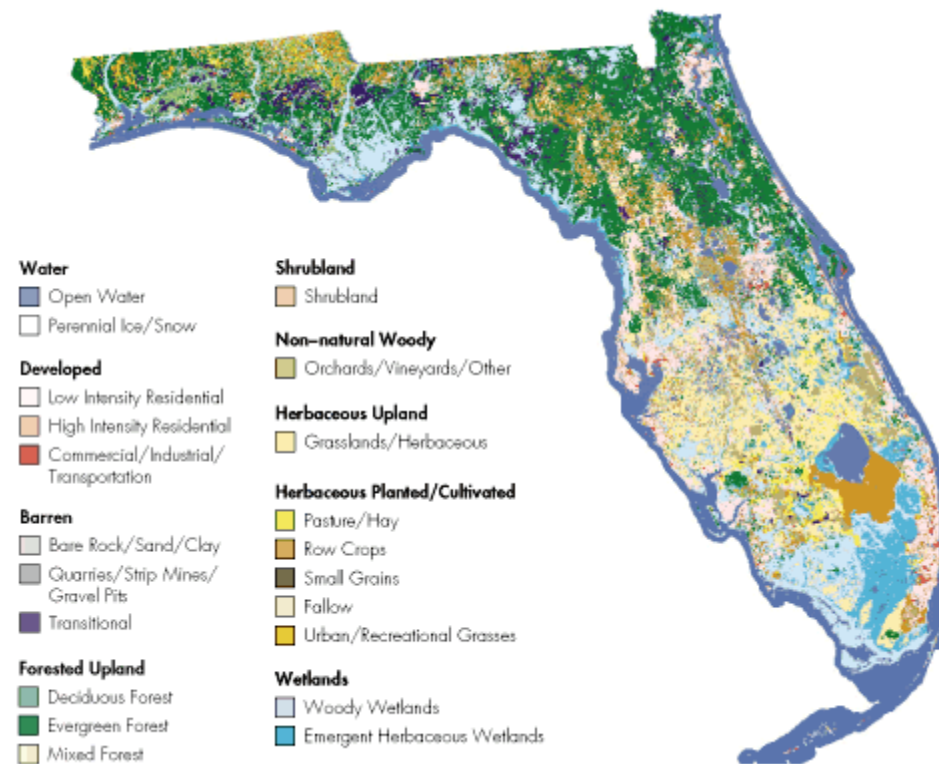# *Brief History of Cartography*

Now -- GIS

Map Design Factors

- ☀ Purpose
  - – Why was the map produced?
- ☀ Reality (extent, shape of features)
- ☀ Available Data
- ☀ Map Scale
- ☀ Intended Audience
  - – Specialists? General Public?
- ☀ Medium – hard or softcopy?
  - – In a report?
  - – On a wall?
  - – On the Web?
  - – Will map be static or interactive?
  - – What is the page size or image dimensions?

You may need to produce several versions of a map, each catered to a different audience or for a different medium

Map Design Factors

✳ Good legend and layout

Water
■ Open Water
□ Perennial Ice/Snow

Developed
□ Low Intensity Residential
□ High Intensity Residential
■ Commercial/Industrial/Transportation

Barren
□ Bare Rock/Sand/Clay
■ Quarries/Strip Mines/Gravel Pits
■ Transitional

Forested Upland
■ Deciduous Forest
■ Evergreen Forest
□ Mixed Forest

Shrubland
□ Shrubland

Non–natural Woody
□ Orchards/Vineyards/Other

Herbaceous Upland
□ Grasslands/Herbaceous

Herbaceous Planted/Cultivated
□ Pasture/Hay
■ Row Crops
■ Small Grains
□ Fallow
□ Urban/Recreational Grasses

Wetlands
□ Woody Wetlands
■ Emergent Herbaceous Wetlands

Mapmaking Principles

* A map should stand alone
  - Should present information without need for extraneous explanation or support
  - Along with data area (map body) a layout should include these *primary map elements*:
    * Good title
    * Subtitle (if appropriate)
    * Legend (** with **"English"** layer and item names, **not** names of files or fields **)
    * Scale (bar and or text)
    * North arrow
    * Date
    * Data source, citations
    * Author
    * Neatline (page border)

Mapmaking Principles

✸ Bad legend vs. Good legend

☐ 🗇 **Layers**
  ☐ ☑ MGISDATA.TOWNS_POLYM **File name**
    ☐ <all other values> **Turn this off**
      TYPE **Field name**
    ☐ C
    ☐ T **Category data values**
    ☐ TC

☐ 🗇 **Layers**
  ☐ ☑ Massachusetts Municipalities
      Type of Government
    ☐ City
    ☐ Town
    ☐ Town with City form of government

Default legend in ArcMap – a no-no for finished maps!!

Better!! Look at metadata for "English" text

Mapmaking Principles

* *Secondary map elements:*
  - Inset/locator map (use "Extent Rectangles" in ArcMap)
  - Graticules
  - Tables
  - Charts
  - Graphs
  - Text boxes
  - Projection
  - Images, graphics, logos
  - Map number, if series
  - Copyright
  - Disclaimer, "DRAFT"
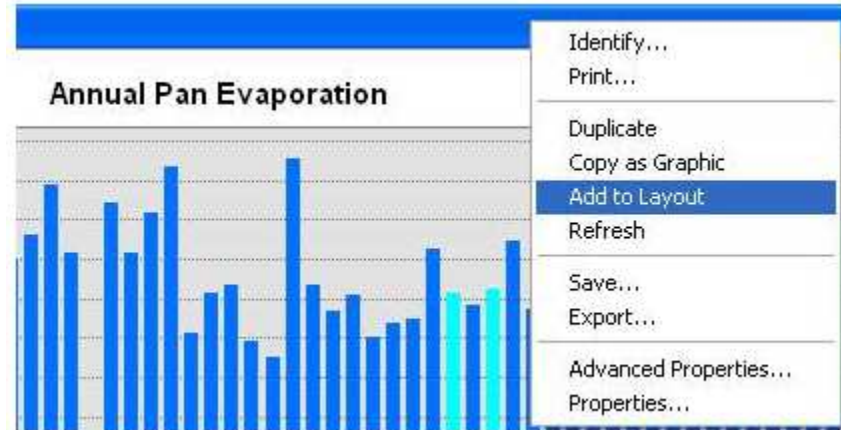
Other Considerations

* Document
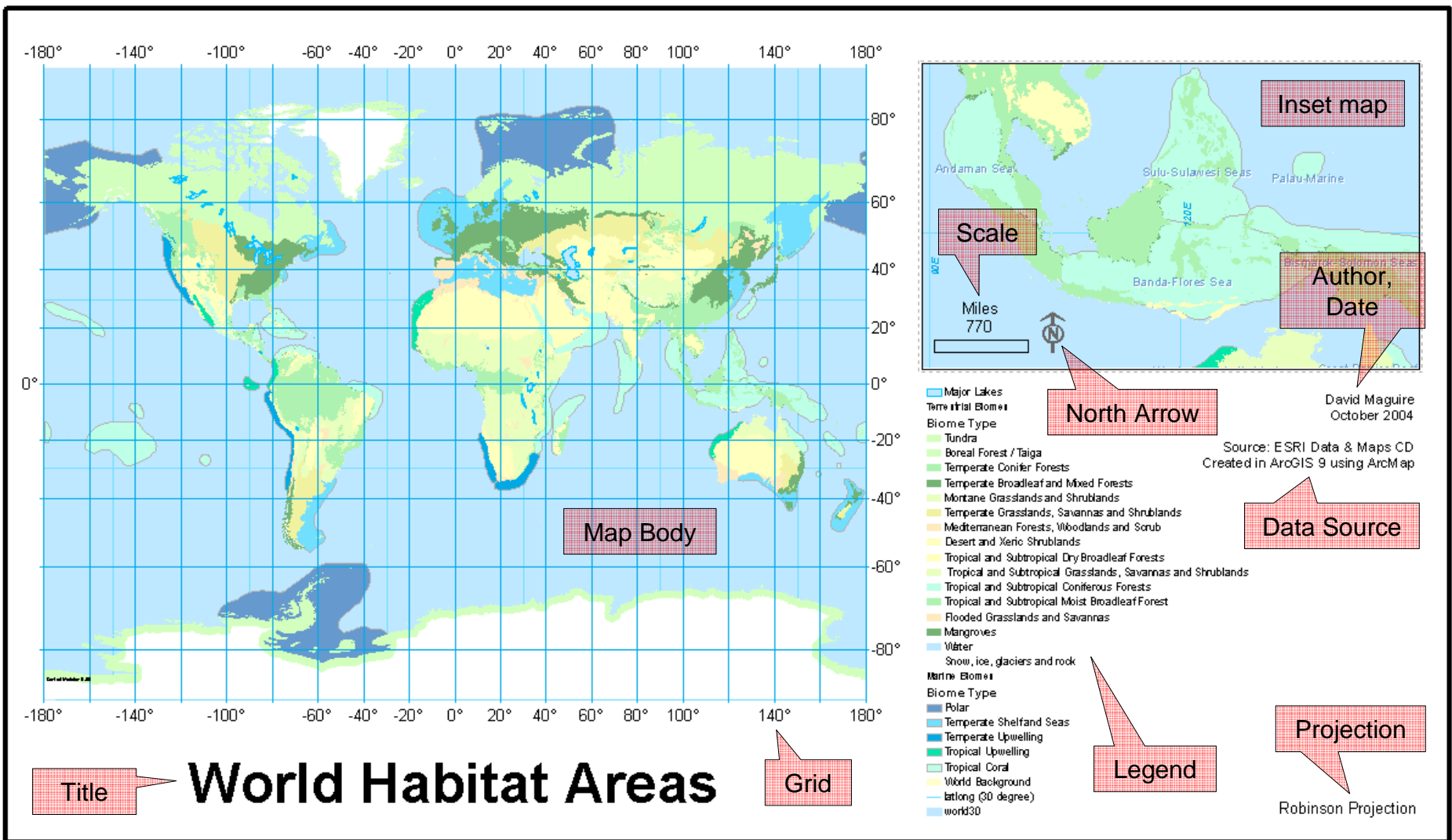 - Keep track of all details, big or small
* Evaluate
  - Does the map accomplish its goal?
* Review
  - Have others critique your map
  - Re-design if necessary

See pages 24-25 and 46-47 in Making Maps

# *Principal Layout Components*

World Habitat Areas

Mapmaking Principles

- **Visual balance** is important for all maps, regardless of purpose or audience
  - Visual harmony and symmetry among elements
  - Proper sizing of components – *visual hierarchy*
  - Colors should not clash and should be distinguishable; For more on color see:
    - https://blogs.esri.com/esri/arcgis/2012/04/12/colors-in-arcgis-symbols/
    - http://www.personal.psu.edu/cab38/ColorBrewer/ColorBrewer_intro.html
  - Figure-ground
    - Main features should stand out, not be lost among reference layers (which should fade to background)

Visual Balance

Poor balance among elements

Counties and Towns
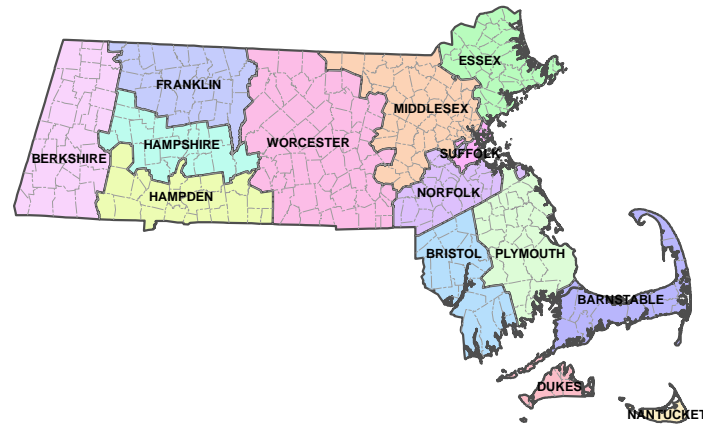
Legend

------ MGISDATA.TOWNS_ARC

MGISDATA.COUNTIES_POLY

- <Null>
- BARNSTABLE
- BERKSHIRE
- BRISTOL
- DUKES
- ESSEX
- FRANKLIN
- HAMPDEN
- HAMPSHIRE
- MIDDLESEX
- NANTUCKET
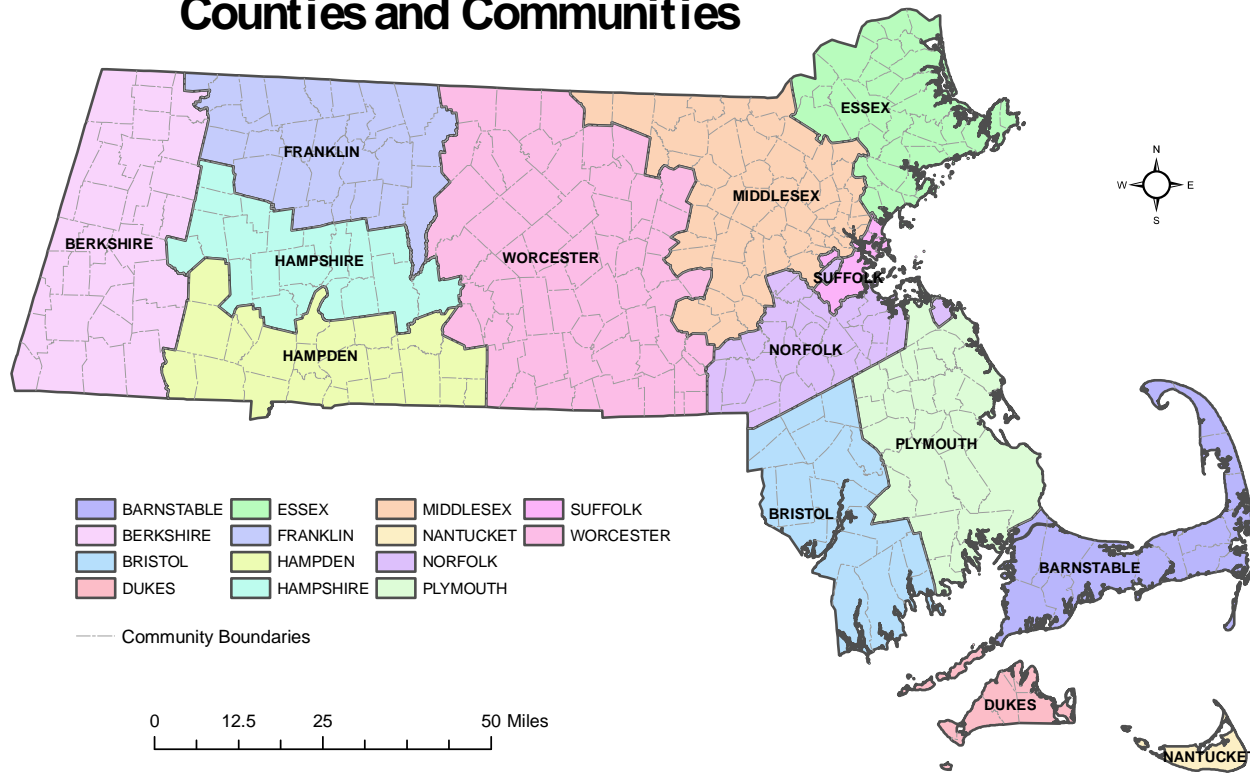- NORFOLK
- PLYMOUTH
- SUFFOLK
- WORCESTER

0   28,000   56,000   112,000 Meters

# *Visual Balance*

Better Visual Balance

Comonwealth of Massachusetts
Counties and Communities

ESSEX
FRANKLIN
MIDDLESEX
BERKSHIRE
HAMPSHIRE
WORCESTER
SUFFOLK
HAMPDEN
NORFOLK
PLYMOUTH
BRISTOL
BARNSTABLE
DUKES
NANTUCKET

	BARNSTABLE		ESSEX		MIDDLESEX		SUFFOLK
	BERKSHIRE		FRANKLIN		NANTUCKET		WORCESTER
	BRISTOL		HAMPDEN		NORFOLK		
	DUKES		HAMPSHIRE		PLYMOUTH		

--- Community Boundaries

0   12.5   25   50 Miles

Map produced by the Geographic Information Technologies
lab at UMass-Boston, November 14, 2004.
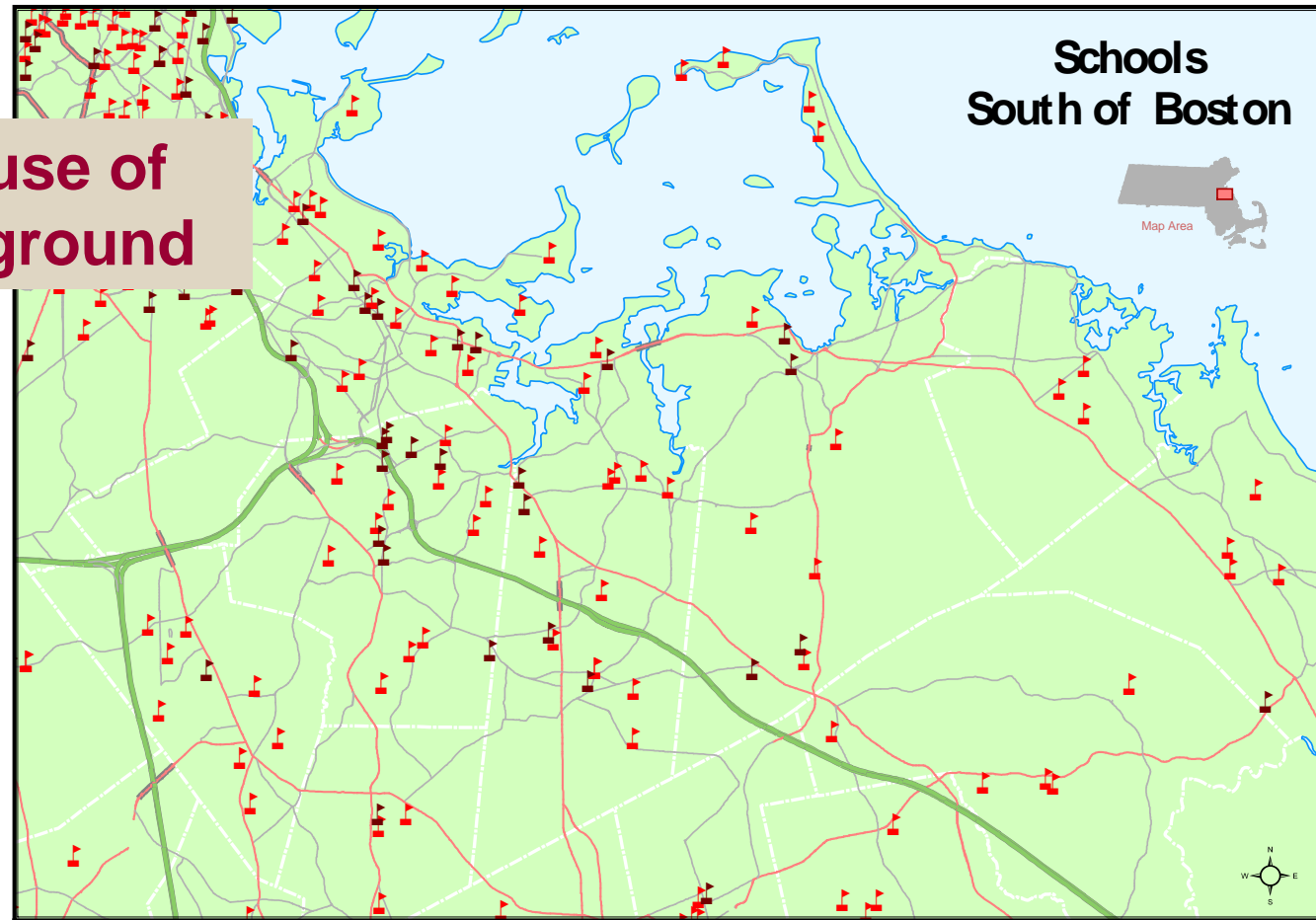*Data from MassGIS.*

Figure-ground

Poor use of figure-ground

Schools
South of Boston

PRI
PUB
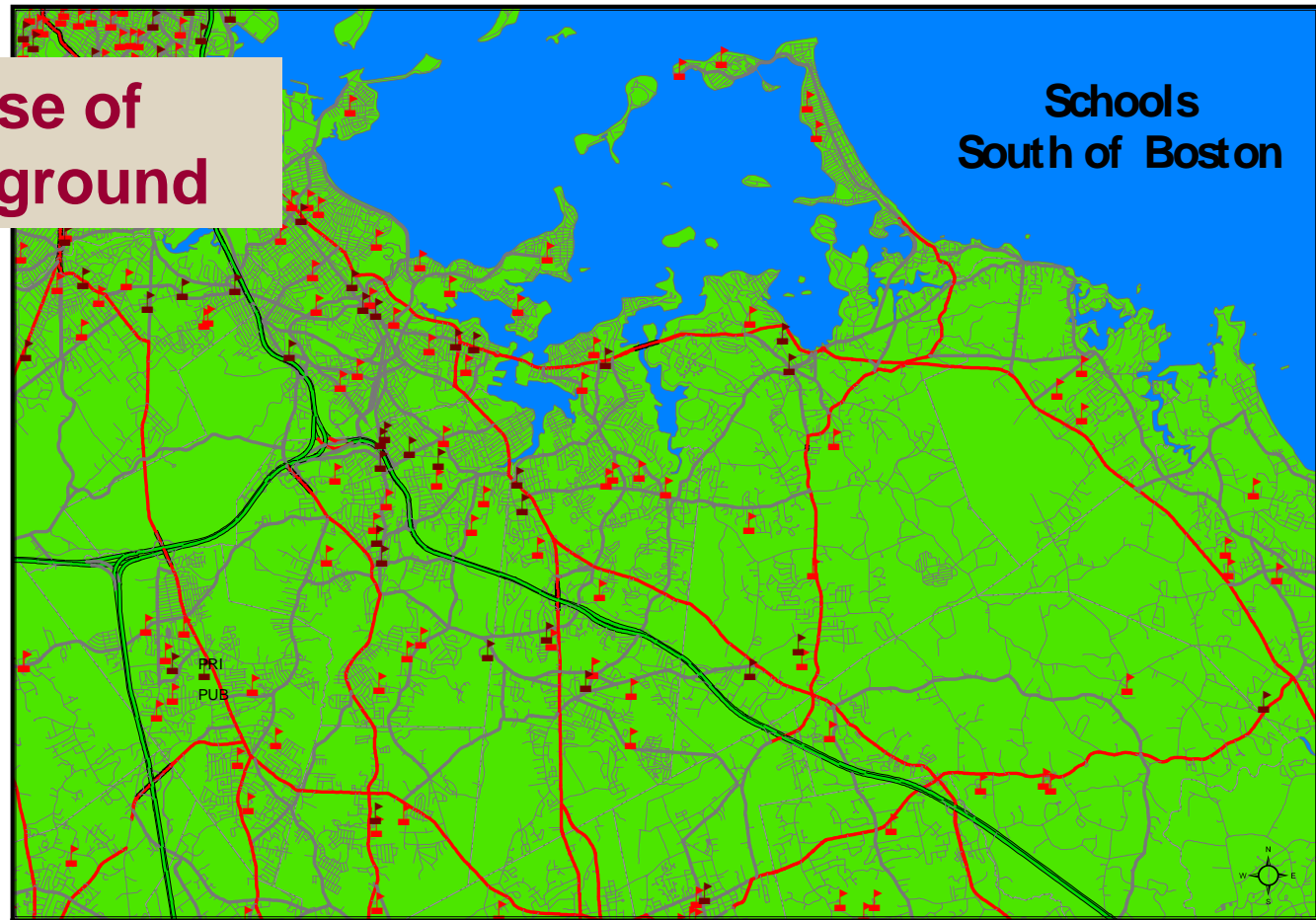
PRI
PUB

| 0 | 1.25 | 2.5 | | 5 Miles |

Map produced by the Geographic Information Technologies lab at UMass-Boston, November 14, 2004. Data from MassGIS.

Figure-ground

Better use of figure-ground

Schools
South of Boston

Map Area

Private School
Public School

0   1.25   2.5   5 Miles

Map produced by the Geographic Information Technologies
lab at UMass-Boston, November 14, 2004.
Data from MassGIS.

Mapmaking Principles

* GIS maps typically avoid the fancy artwork of older-style maps

  - Should focus on message of the map (data frame), without distractions

  - But, maps should not be boring – use capabilities of software to create visually pleasing layouts
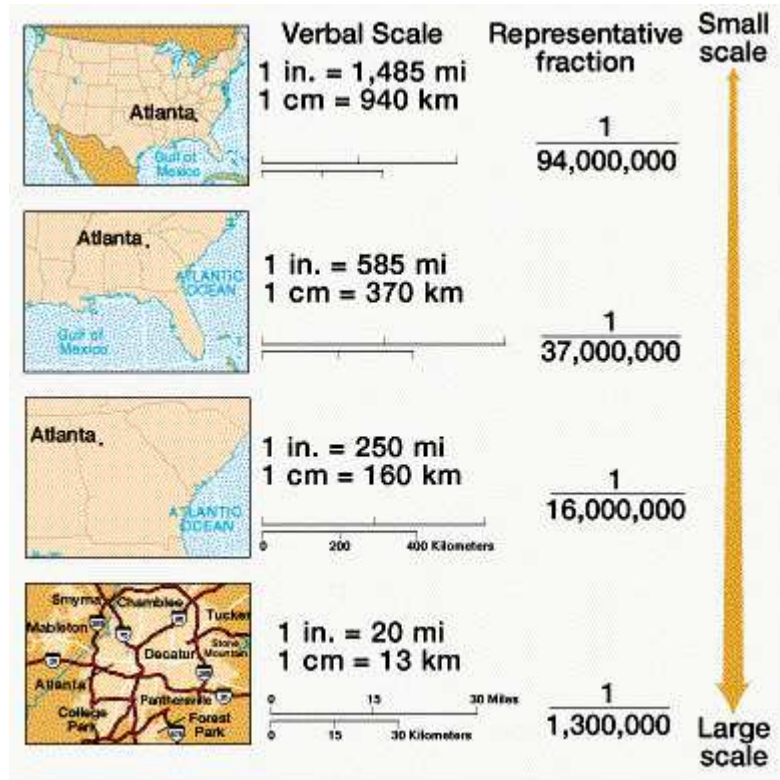
  - Map vs. poster display

www.shutterstock.com · 34517803

Characteristics of Maps

✳ Reduction

– Maps are not just a representation of an area, but a reduction of that area, so only certain things can be included in a map, depending on the map's size, what you intend to communicate, and what level of detail can be included. This relationship between reality and the reduced representation is called **scale**.

| Verbal Scale	Representative fraction	Small scale
1 in. = 1,485 mi 1 cm = 940 km	$\frac{1}{94,000,000}$	
1 in. = 585 mi 1 cm = 370 km	$\frac{1}{37,000,000}$	
1 in. = 250 mi 1 cm = 160 km	$\frac{1}{16,000,000}$	
1 in. = 20 mi 1 cm = 13 km	$\frac{1}{1,300,000}$	Large scale

Characteristics of Maps

* Transformation
    - All maps involve a geometrical transformation - depicting the curved surface of the earth onto a flat surface, such as a computer screen or a piece of paper. A systematic transformation is called a **map projection**.
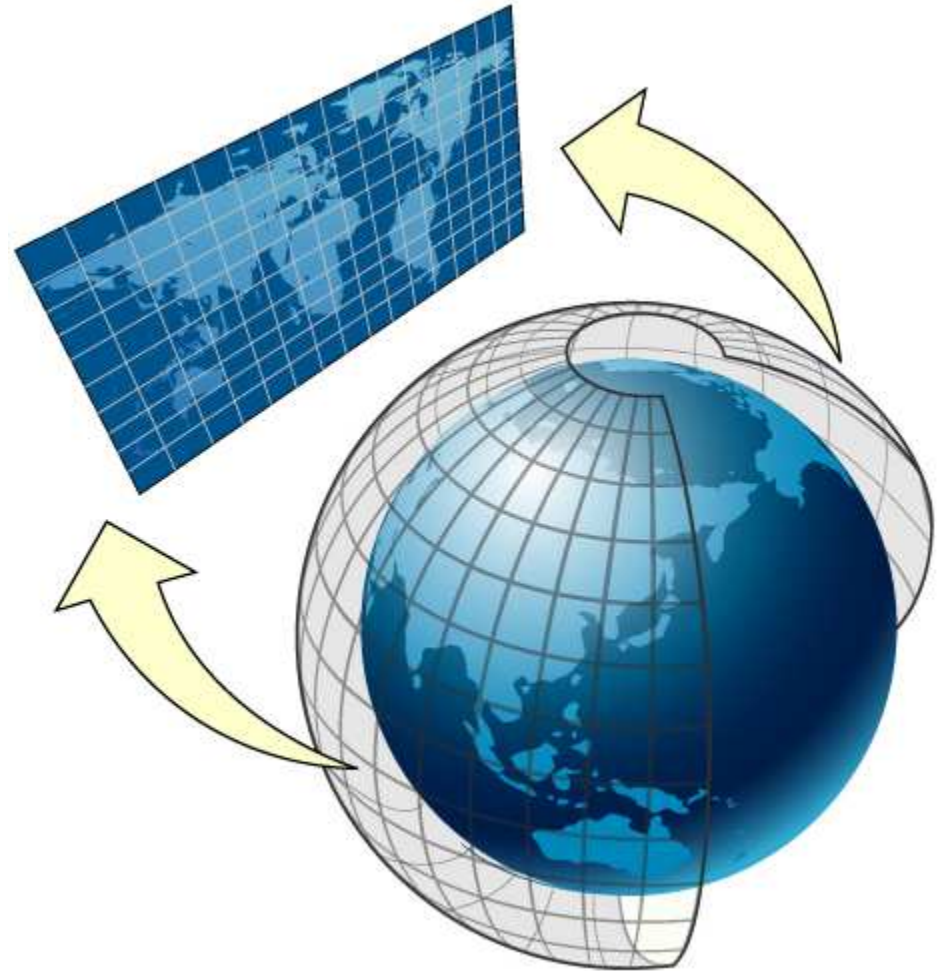
Characteristics of Maps

* Abstractions
  - All maps are abstractions of reality, which is too complex to be displayed in its entirety on a map, so the cartographer must decide what to include. Features are often **generalized**.
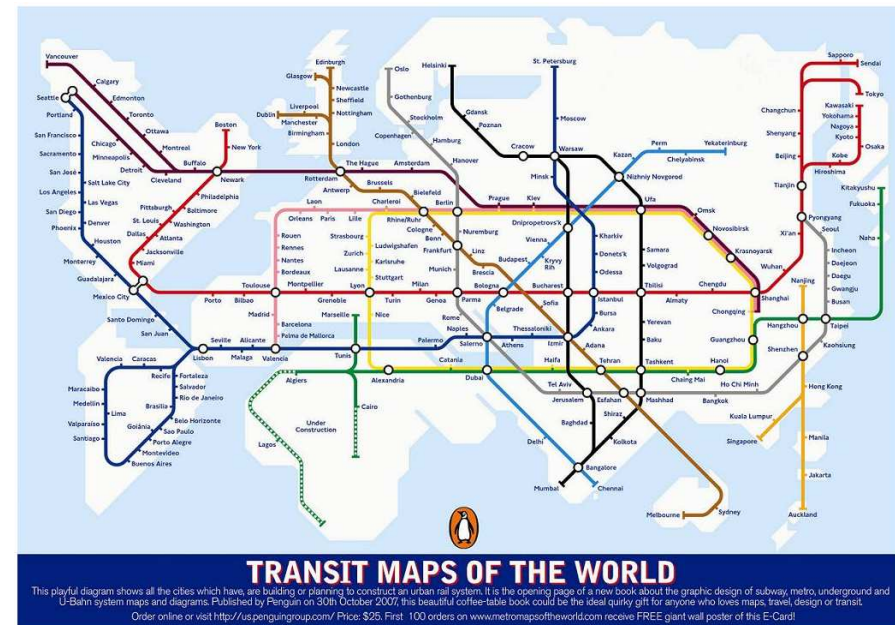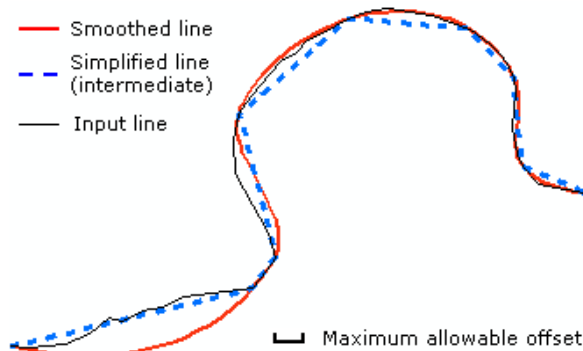
Characteristics of Maps

✳ Symbolization

– All maps use signs, which make up the symbolization of cartography. Since these are not universal signs, there must be a **legend** to describe what they represent in the world.

| Mile Marker | Mountain Pass | Overpass | Parking | Private Field |
| Road Closure | Road Work | Sailing | Scales | Seaplane |

Characteristics of Maps

✳ Symbolization

– Consists of various kinds of **marks - lines, dots, colors, tones, patterns, textures, etc**. Their selection and the way they are assembled onto a map greatly affect how the map communicates.
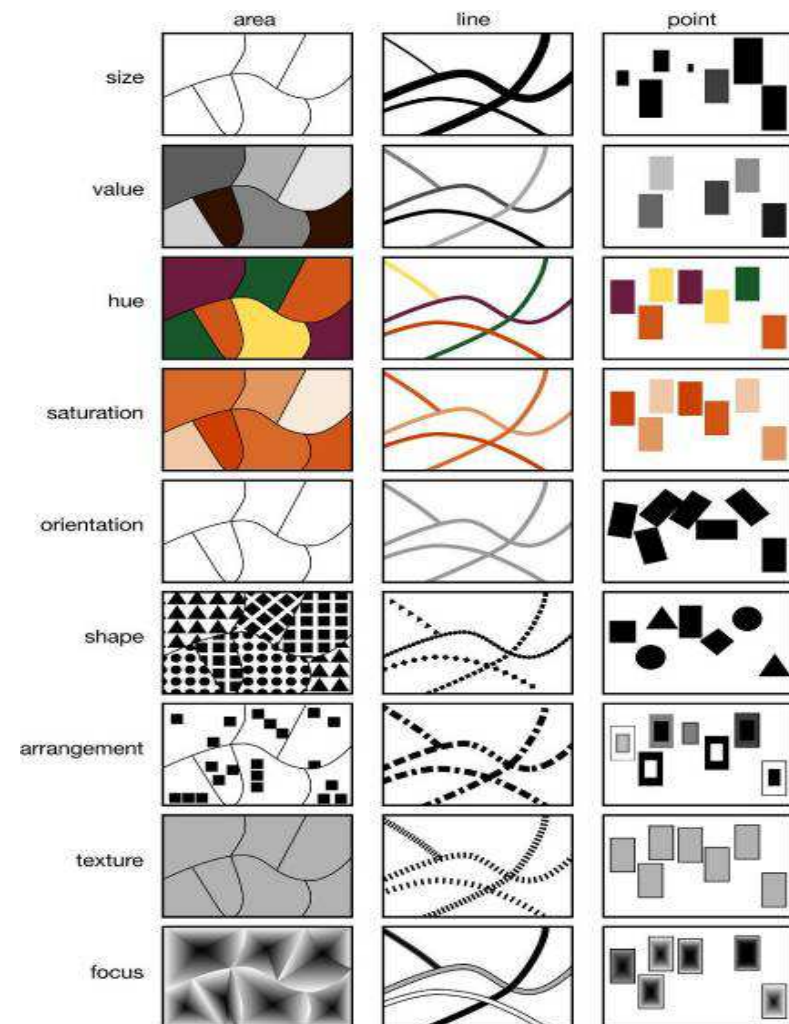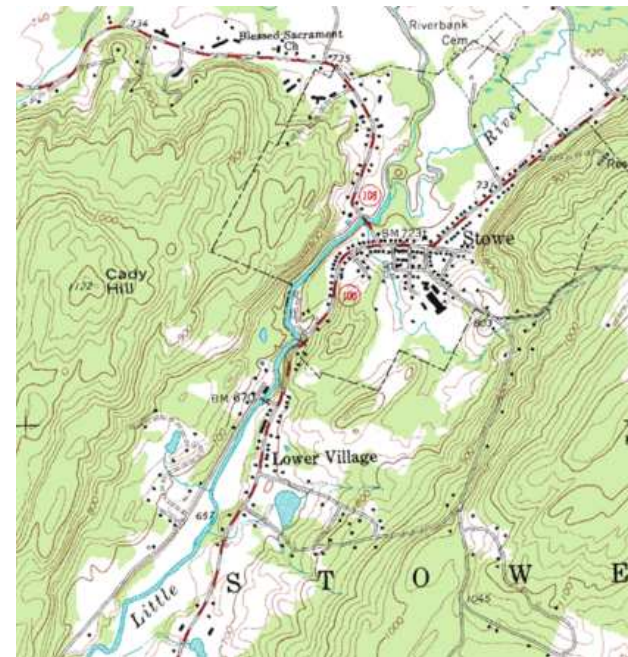
Categories of Maps

* Classed by scale
  - the ratio between the dimensions of the map and those of reality
    - **small-scale map** - details are small, covers a large area (1:1,000,000)
    - **large-scale map** - details are large, covers a small area (1:5,000)

Transportation map displayed at a series of map scales

Regional view.

Major roads within the area around Dallas, Texas.

Major roads and prominent features around Long Beach, California.

Local roads and streets are included for all of the U.S., Canada, and for many countries in Europe.
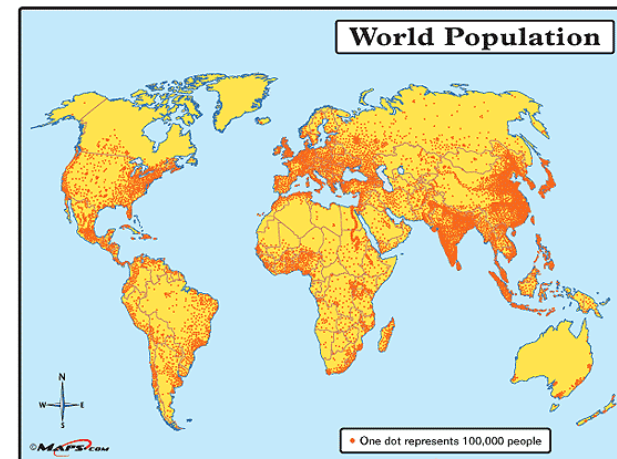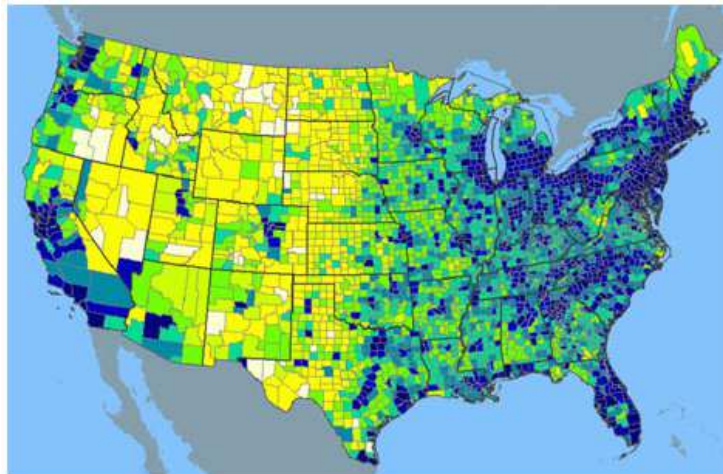
Categories of Maps

✳ Classed by function

   – **General reference maps** - show locations of different features, such as water bodies, coastlines, roads, cultural features (hospitals, schools, recreation facilities, etc)

      • USGS topographic maps

      • AAA road maps

      • Engineering plans
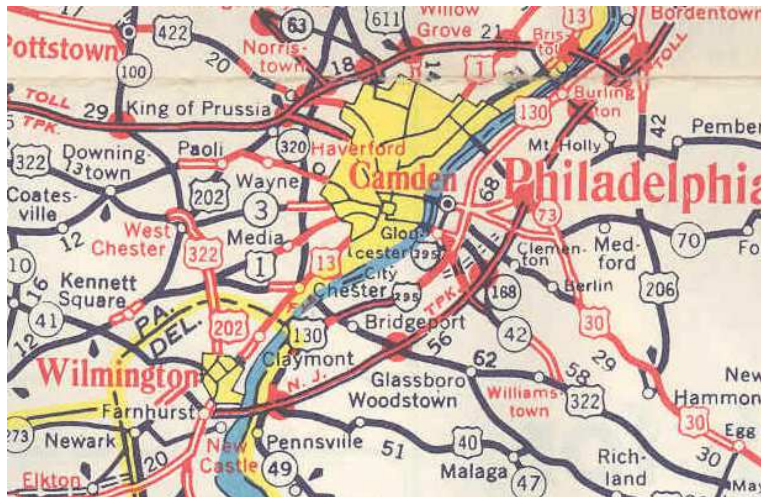
Categories of Maps

✳ Classed by function

  – **Thematic maps** - (special-purpose maps) - display a general impression of a phenomenon's spatial distribution, or the relationship among many attributes, rather than to simply provide location of places

   • spread of diseases around the world
   • pattern of crimes in a city
   • population density in metropolitan areas

World Population
One dot represents 100,000 people

Categories of Maps

* Classed by function
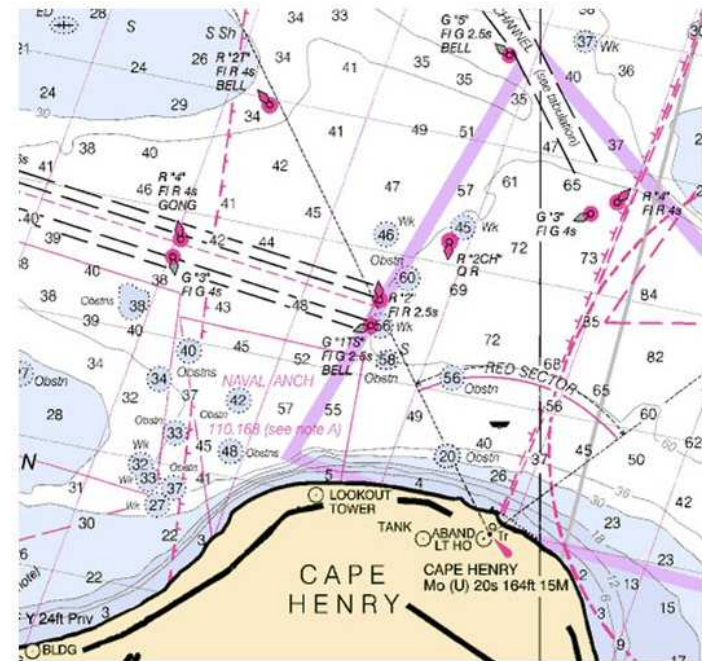 - **Thematic maps**
    * Choropleth (shaded area) maps
    * Dot density
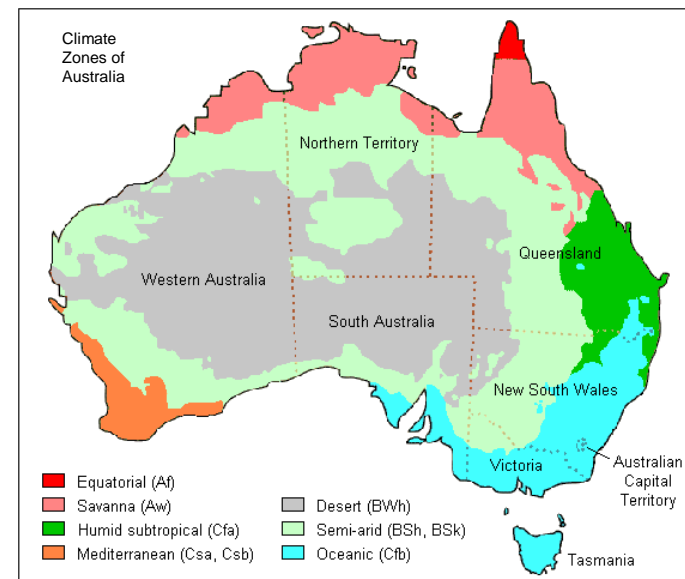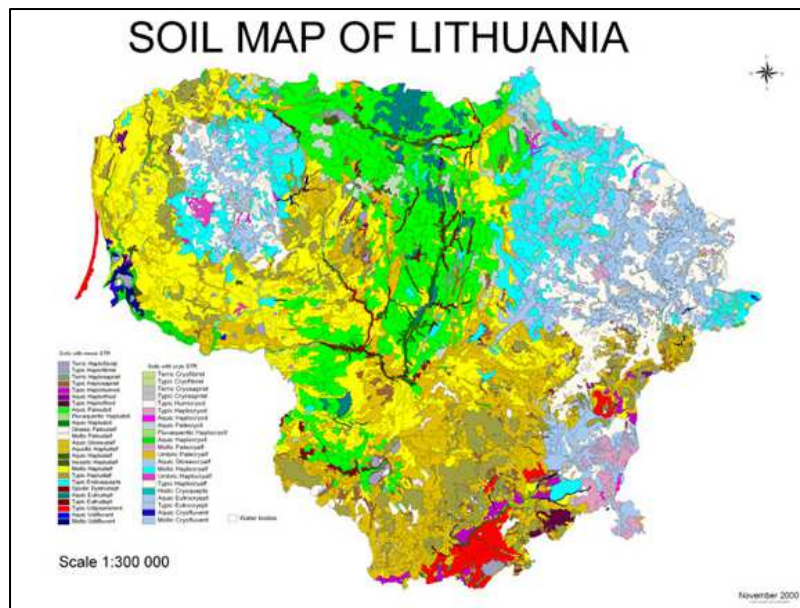   * Graduated symbols (lines and points)

Categories of Maps

✳ Classed by function
  – **Charts** - very accurate, highly detailed maps designed to serve the needs of navigators, nautical and aeronautical. Used for:
    • plotting courses
    • determining positions
    • mark bearings
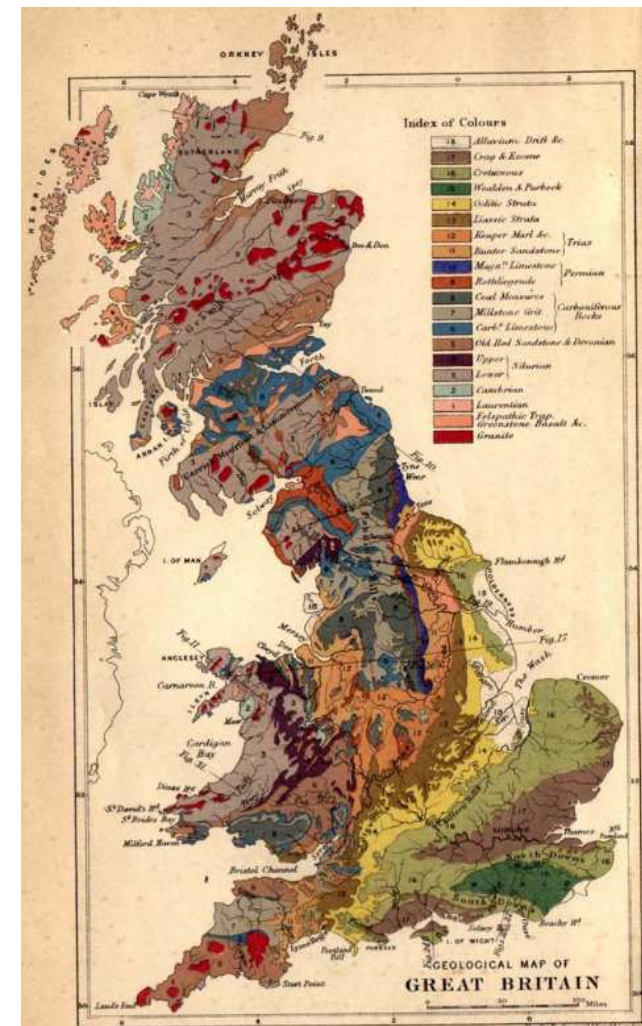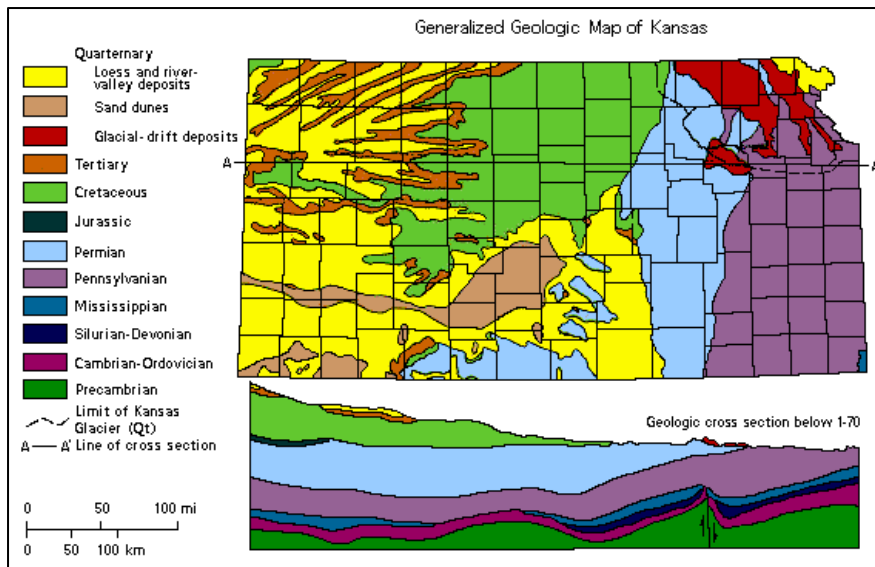 – Ex. - NOAA Nautical Charts

Categories of Maps

* Classed by subject matter
  - Soils, geology, transportation, climate, population…
    - Virtually unlimited the number of maps when grouped by subject matter

SOIL MAP OF LITHUANIA

Scale 1:300 000

November 2000

Climate Zones of Australia

Northern Territory

Queensland

Western Australia

South Australia

New South Wales

Victoria

Australian Capital Territory

Tasmania

Equatorial (Af)
Savanna (Aw)
Humid subtropical (Cfa)
Mediterranean (Csa, Csb)
Desert (BWh)
Semi-arid (BSh, BSk)
Oceanic (Cfb)

Categories of Maps

✳ Classed by subject matter

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✳ Classed by subject matter