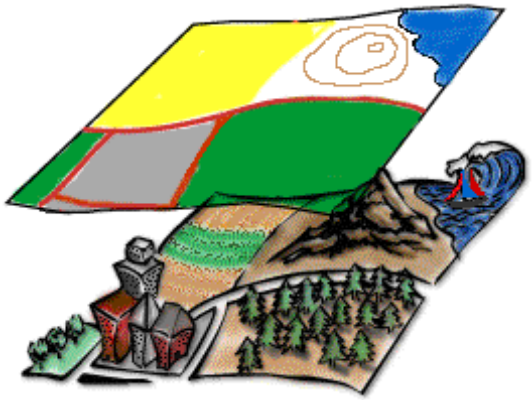
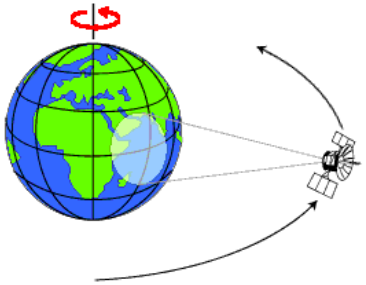
NICHOLAS SCHOOL OF THE ENVIRONMENT AND EARTH SCIENCES

DUKE UNIVERSITY



Fundamentals of Geospatial Analysis

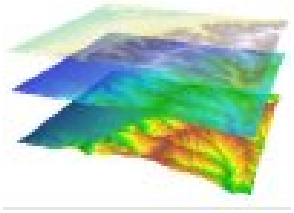
Cartographic Design (part 2)



John Fay & Patrick Halpin

With materials from ESRI's Virtual Campus cartography course

Color Basics



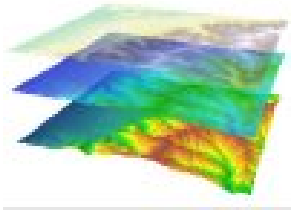
Choosing colors is more than what looks prettiest…

Color choices should reflect natural tendencies (e.g. water is blue), but should also support the map hierarchy.

Color choices will also reflect the final media on which the map will be set.

Ultimately, however, color is limited to what ArcGIS offers you…

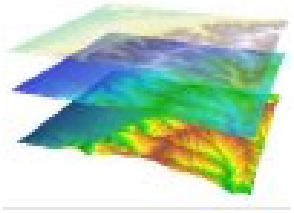
Color in ArcGIS



3 ways to specify color in ArcGIS

- Hue-Saturation-Value (HSV)
- Red-Green-Blue (RGB)
- Cyan-Magenta-Yellow (CMY)

Perceptual dimensions



Trained colorists can distinguish among a million colors!

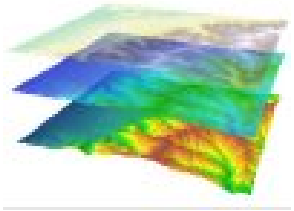
*in pairwise comparisons… (*Tufte: Envisioning Information*)

Most people can discriminate up to 20,000 colors.

Color is a powerful cartographic tool!

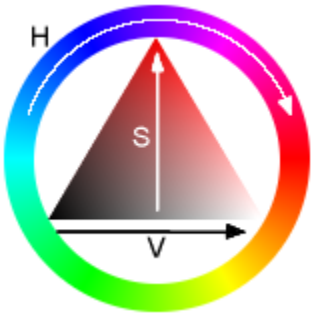
So how do we best use color in maps?

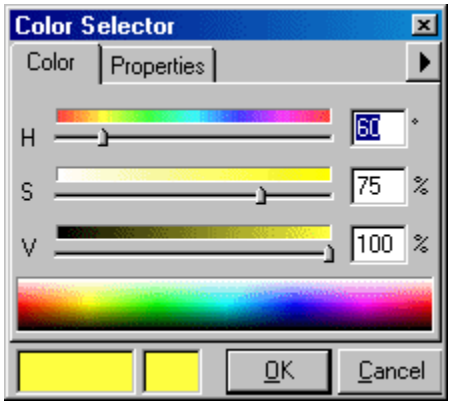
Perceptual dimensions: HSV

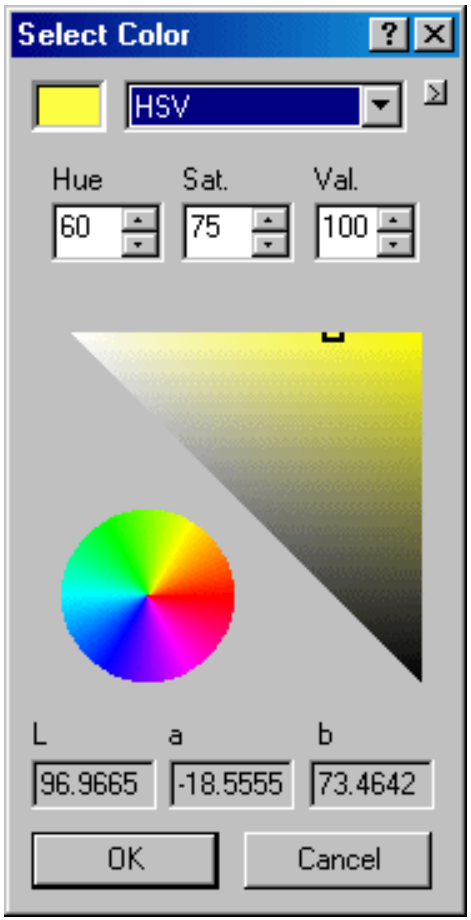


Color can be perceived in three dimensions:

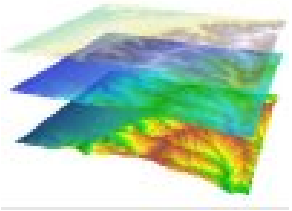
- Hue
- Saturation
- Value (Lightness)

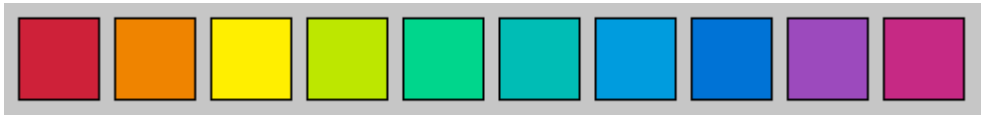






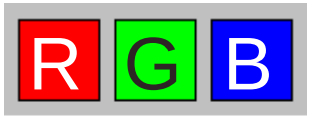
Perceptual dimensions: Hue

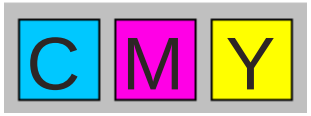




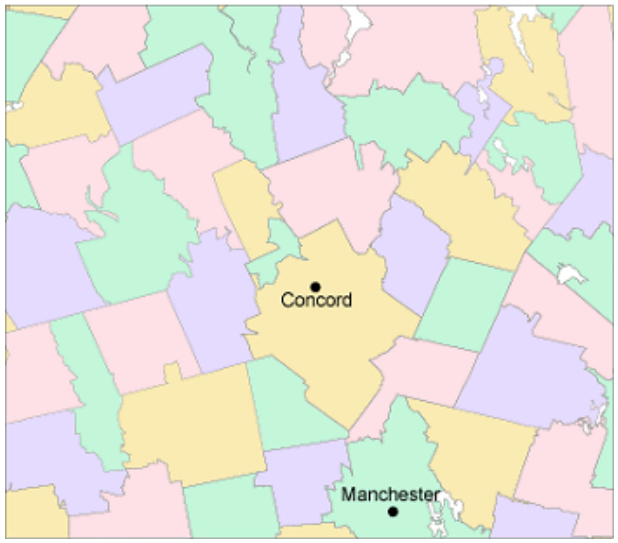
Hue is most related to what we think of as color

Additive (light)

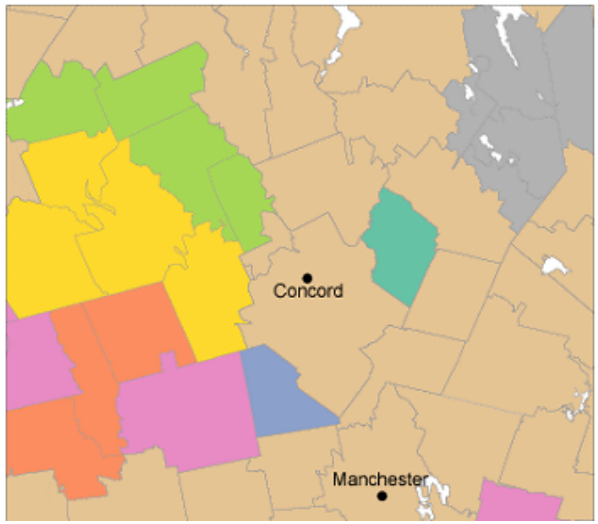




Subtractive (ink)



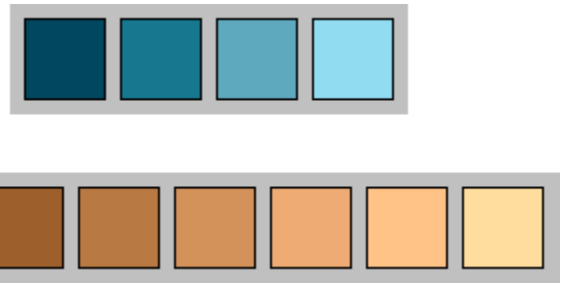
Two maps with features varying only ← in hue →



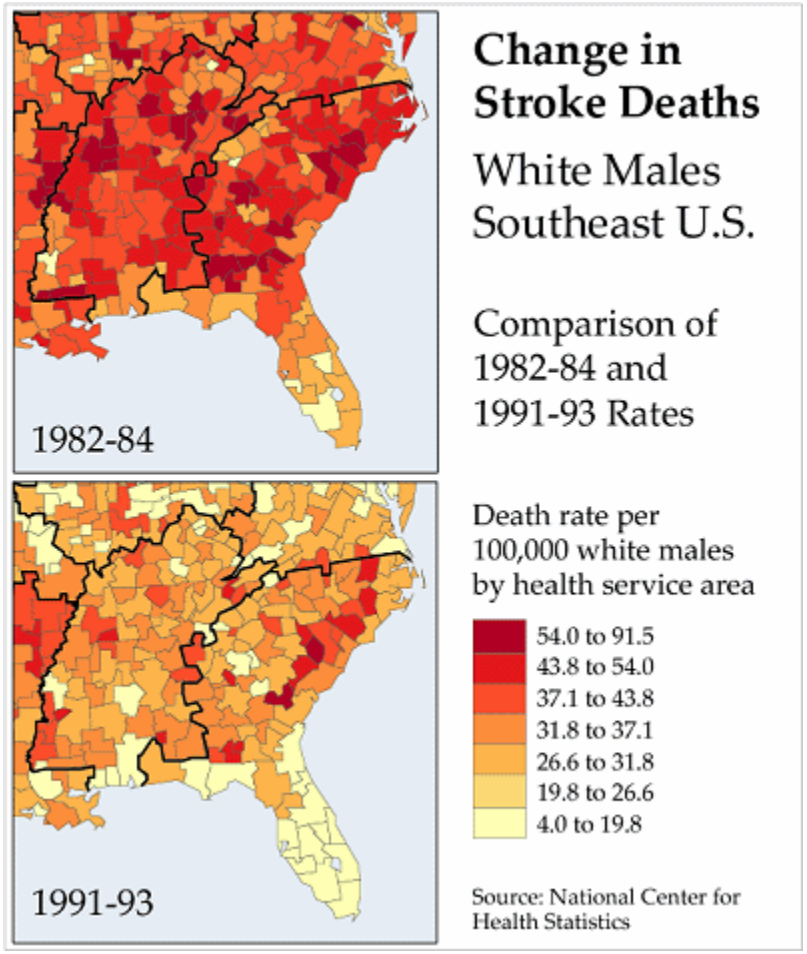
Perceptual dimensions: Value

Value (or Lightness) is most often used to show order within mapped data

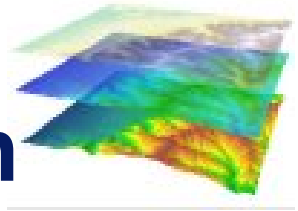
Lightness is a relative measure describing how much light appears to reflect from an object.



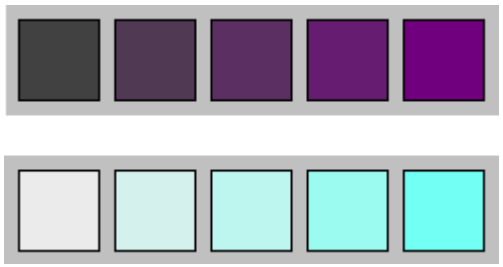
These colors vary only in lightness. Hue and saturation are kept constant.



Perceptual dimensions: Saturation

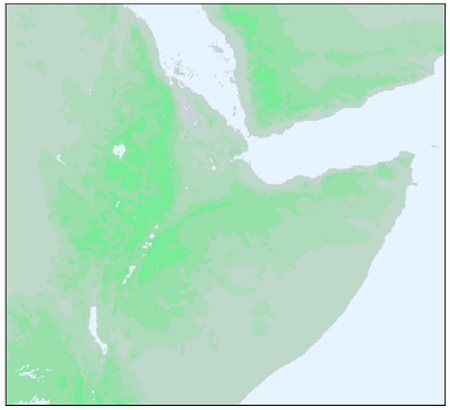


Saturation is a measure of the vividness of a color.

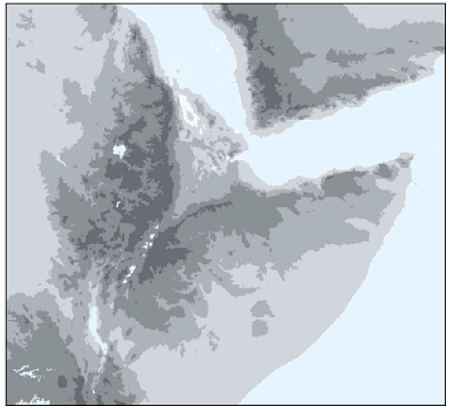


Low saturation values tend to be grayish

Variable saturation

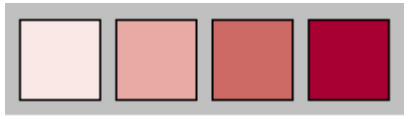


Variable lightness

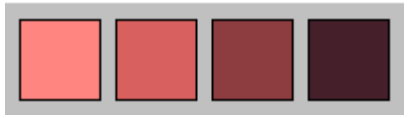


Saturation alone is usually insufficient to display data. Often its used to reinforce value.

Constant hue



Increasing saturation

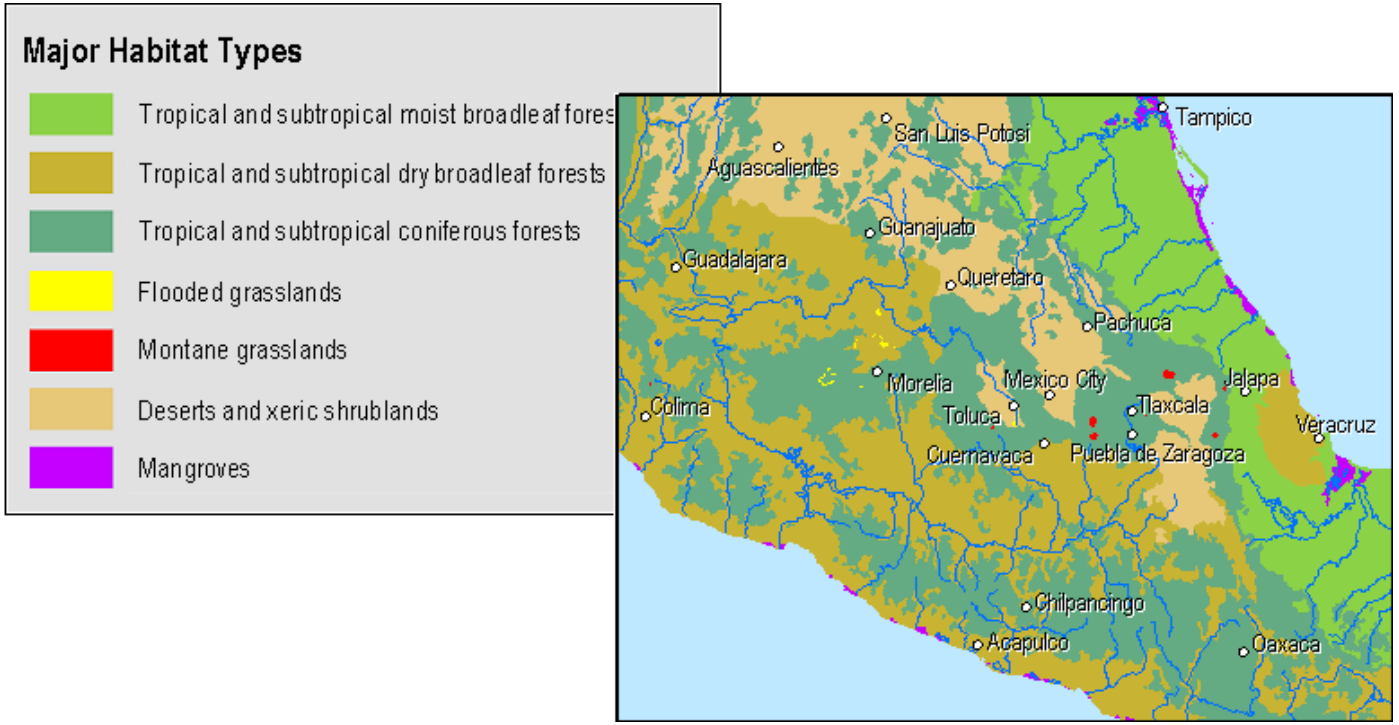


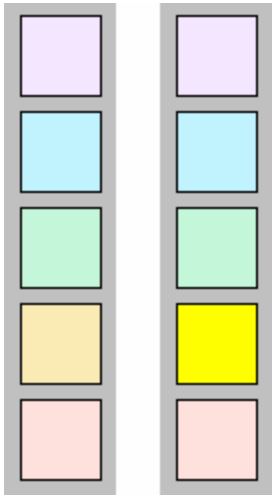
Increasing value

Perceptual dimensions: Saturation

Saturation is the most difficult dimension to use…

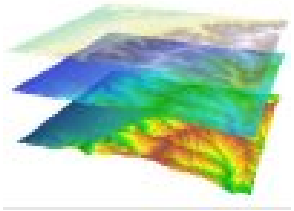
Ignoring saturation can alter the map hierarchy by displaying certain featured more vividly.





Which color has the highest saturation?

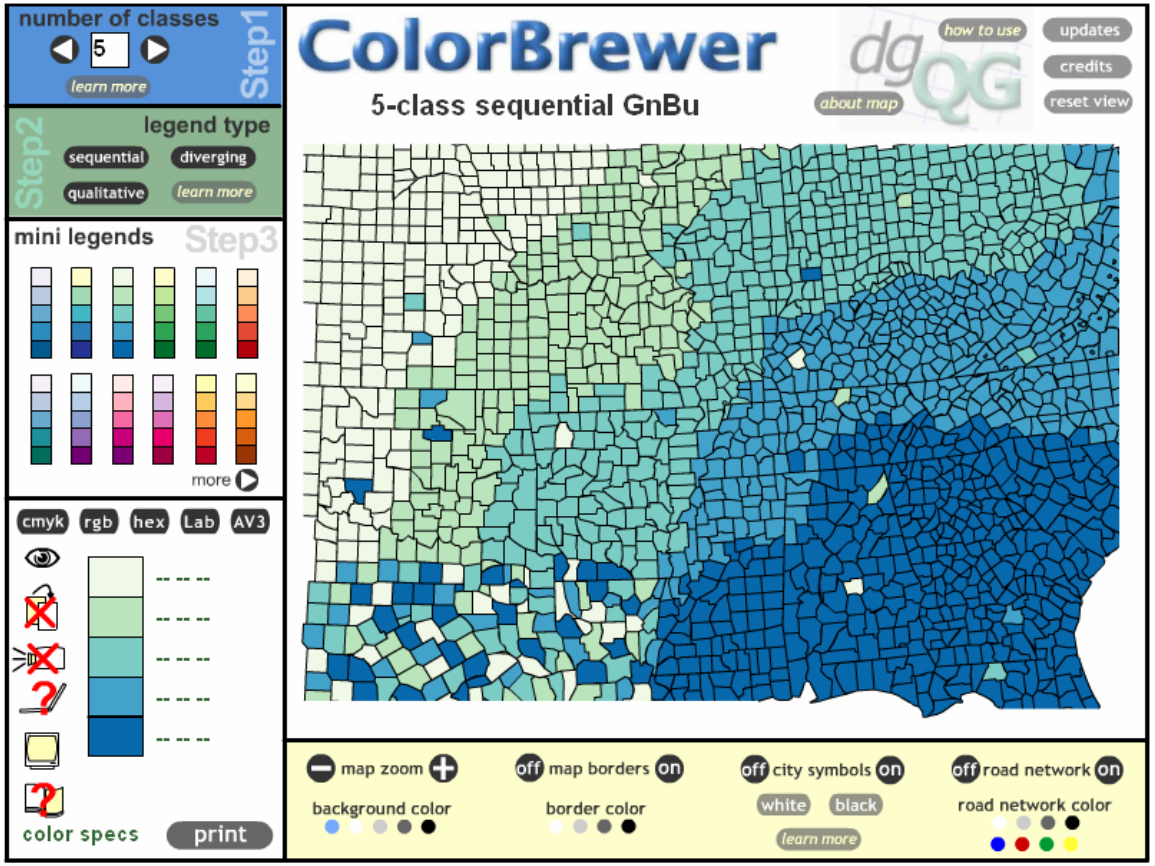
Color Schemes



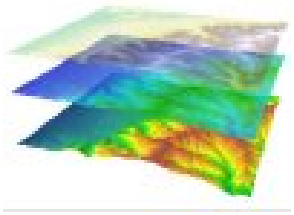
Color scheme structures:

- Sequential
- Diverging
- Qualitative
- Binary schemes

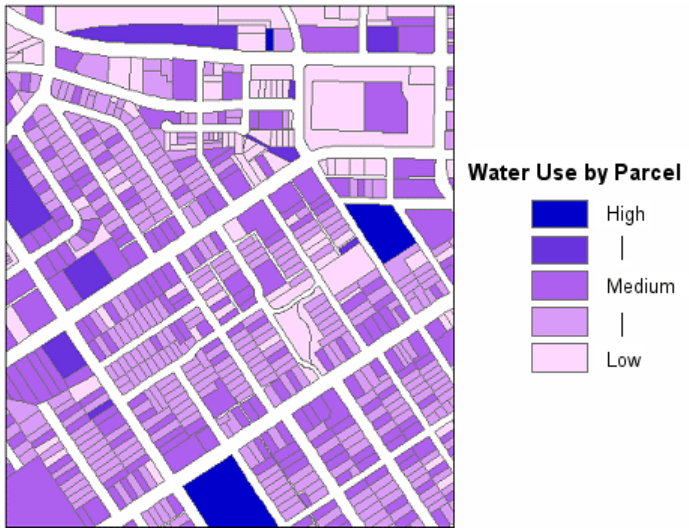
http://www.ColorBrewer.org

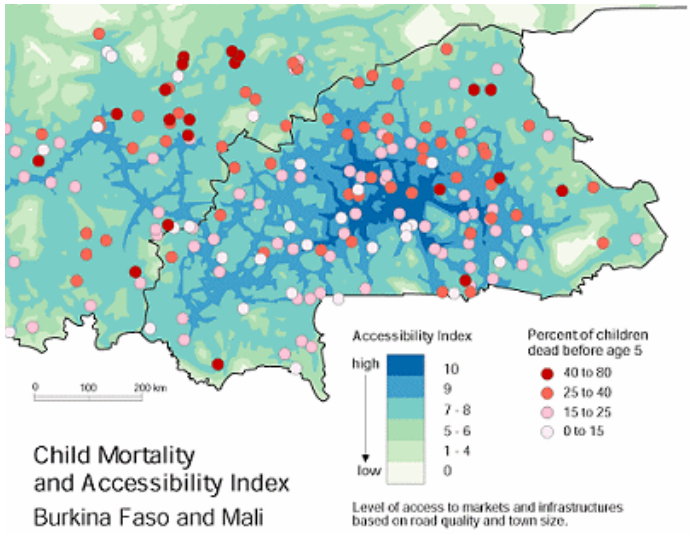


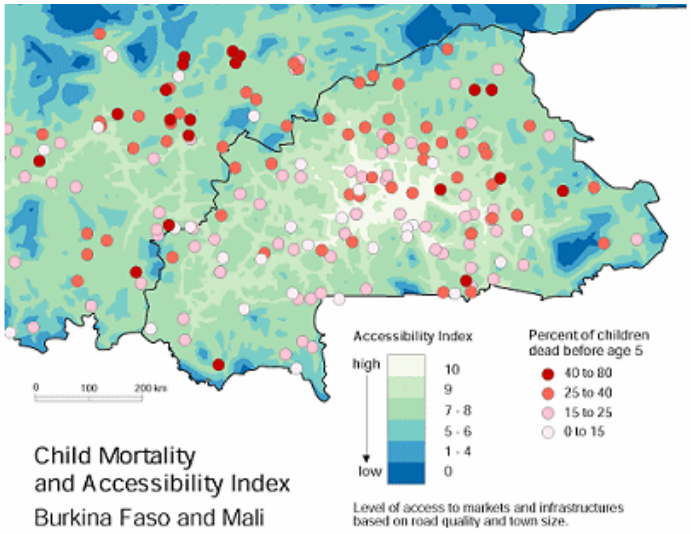
Sequential Color Schemes



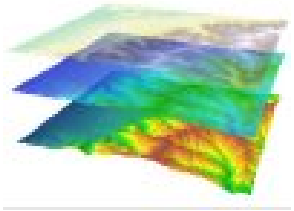
Lightness is used primarily to represent ordered data, but hue can be used as well…



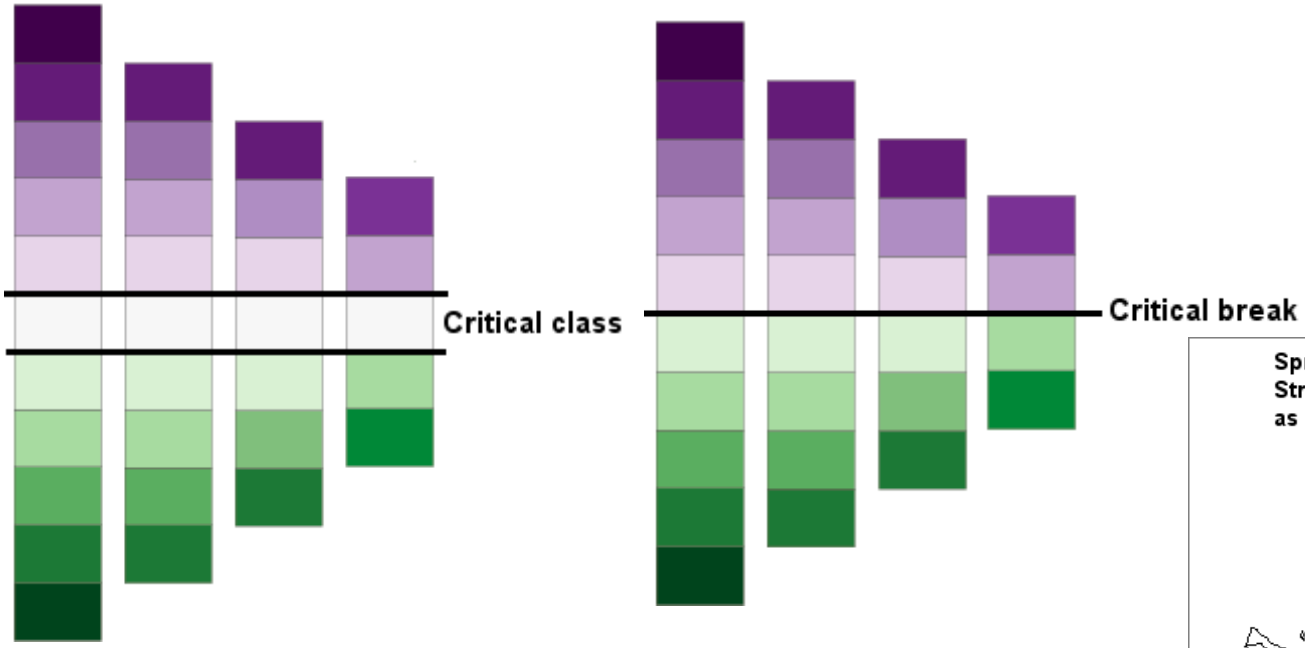


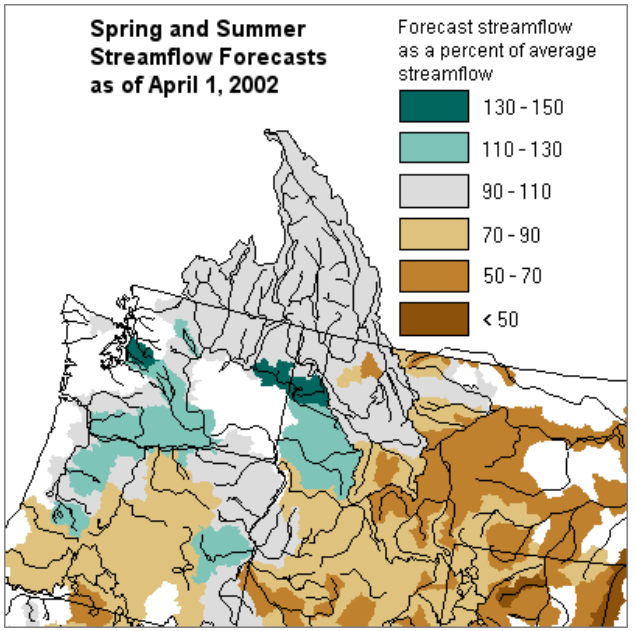


Diverging Color Schemes



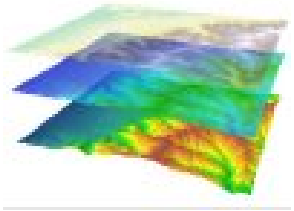
Divergent color schemes emphasize both highs and lows by using variation in both hue and value.



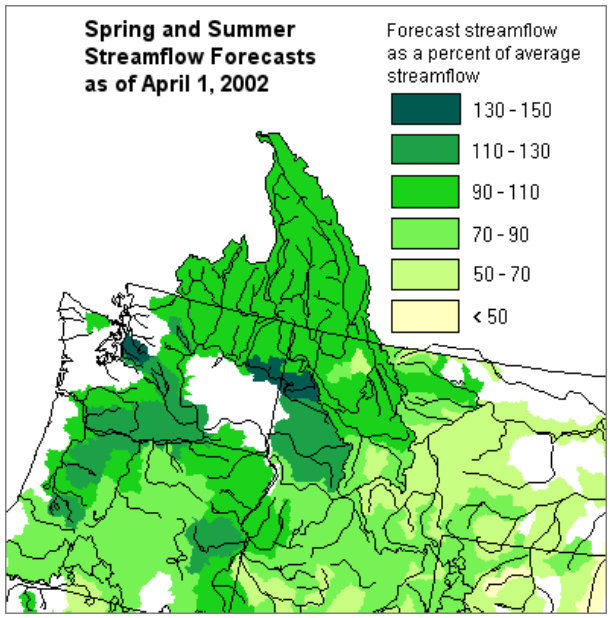


Colors are arranged symmetrically around a median, zero, or threshold value.

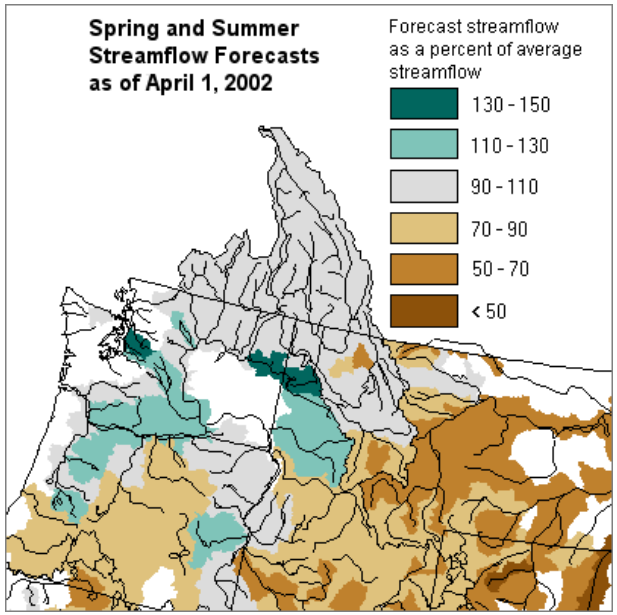
Diverging Color Schemes



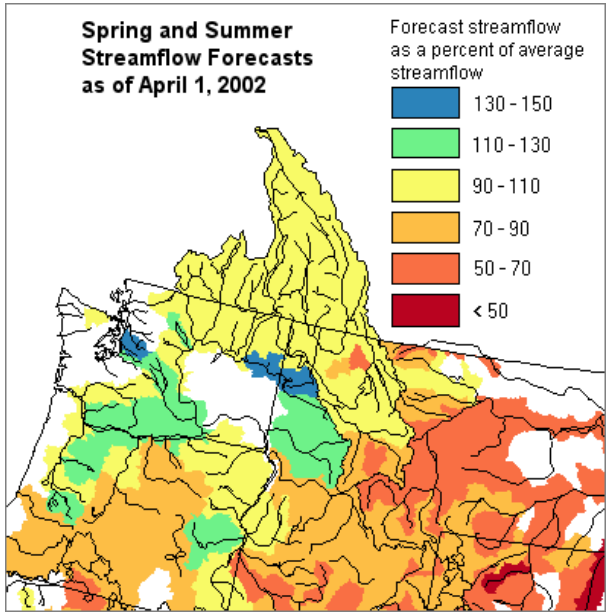
Variation in both lightness and hue can be used to identify a threshold.



Sequential with a different hue for negative values

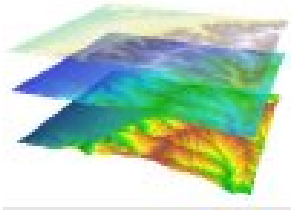


Lightness varied on two hues

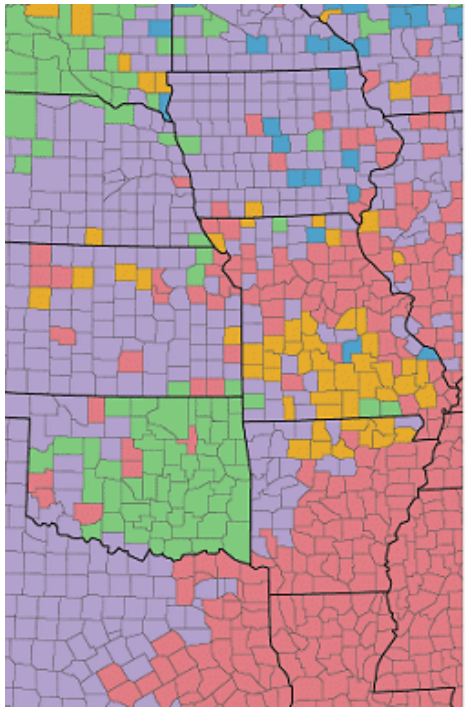


Multi-hue

Qualitative Color Schemes



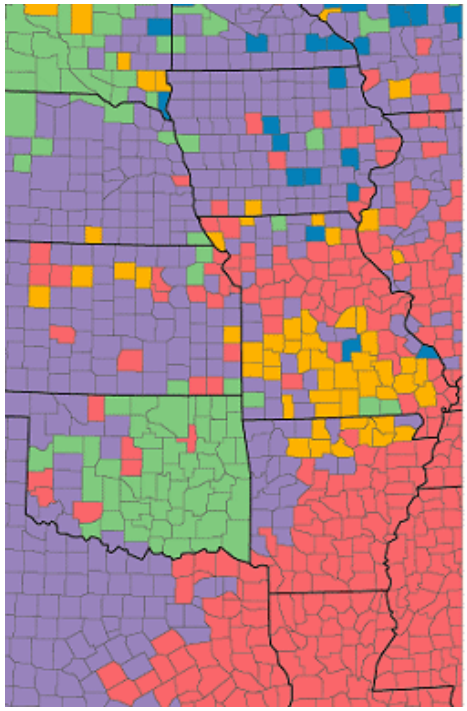
Categorical differences in data are usually represented with differences in hue.



Minority group with highest percent of county population

Excludes White, not Hispanic

- Hispanic or Latino
- Black or African American
- American Indian and Alaska Native
- Asian
- Two or more races, not Hispanic or Latino



Minority group with highest percent of county population

Excludes White, not Hispanic

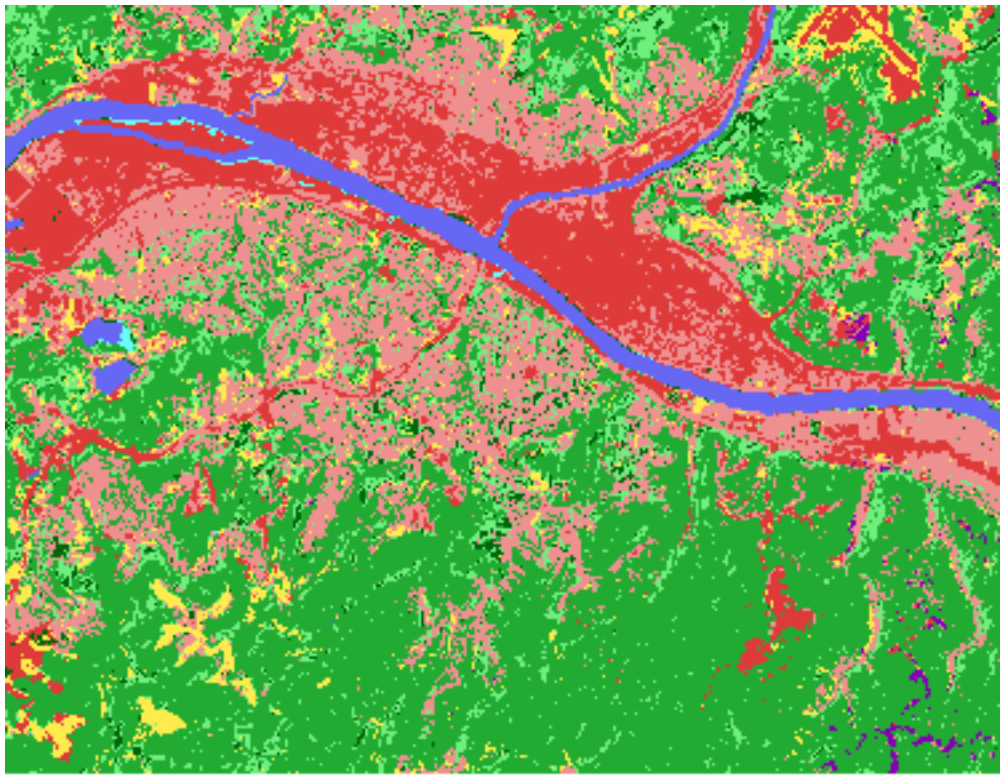
- Hispanic or Latino
- Black or African American
- American Indian and Alaska Native
- Asian
- Two or more races, not Hispanic or Latino

Variations in lightness can elevate some categories in the visual hierarchy.

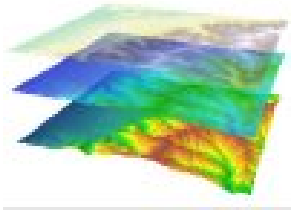
Qualitative Color Schemes

Exploit logical relationships between classes to create color hierarchies when possible.

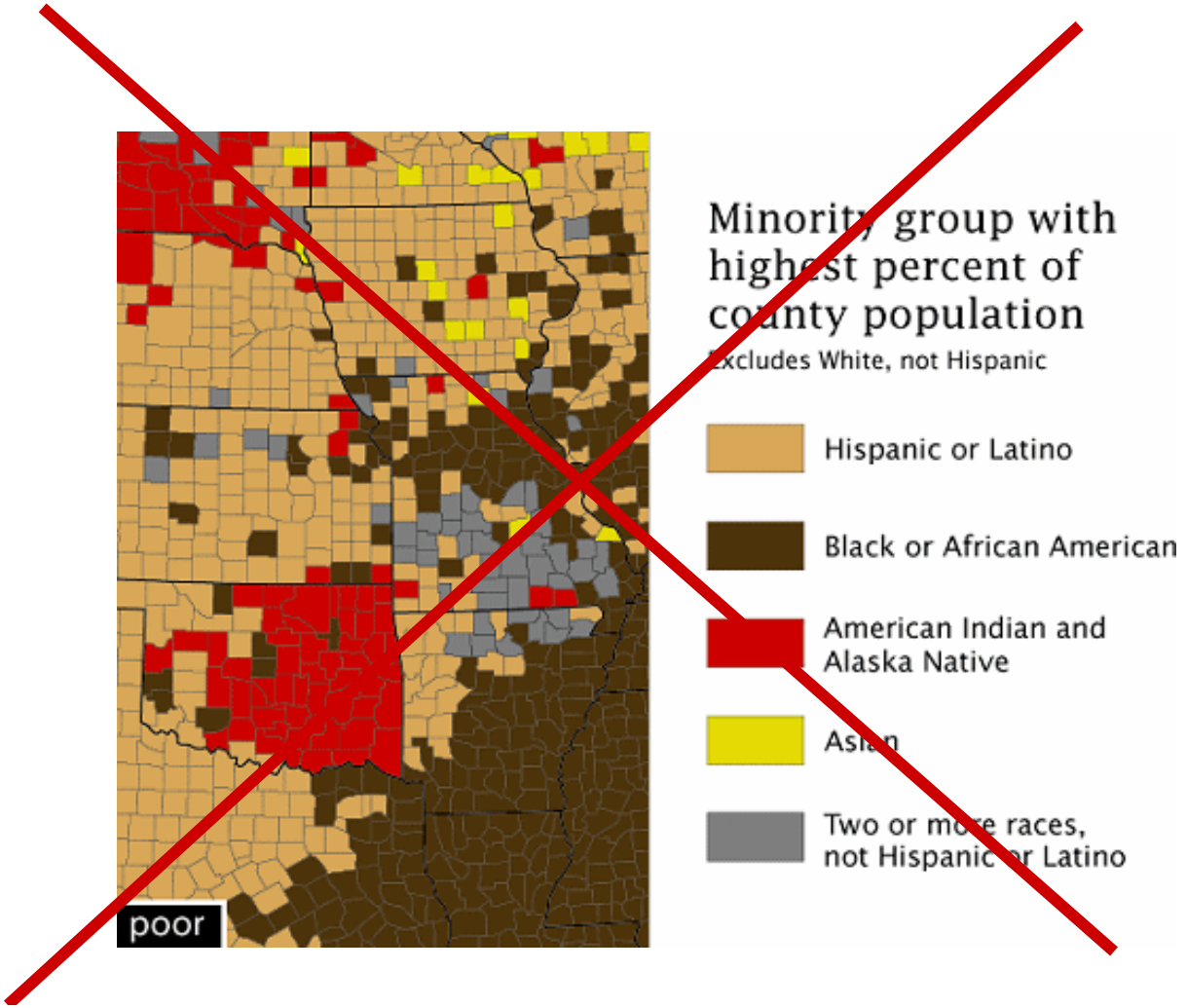
Use more intense colors to make smaller classes more visible



Qualitative Color Schemes



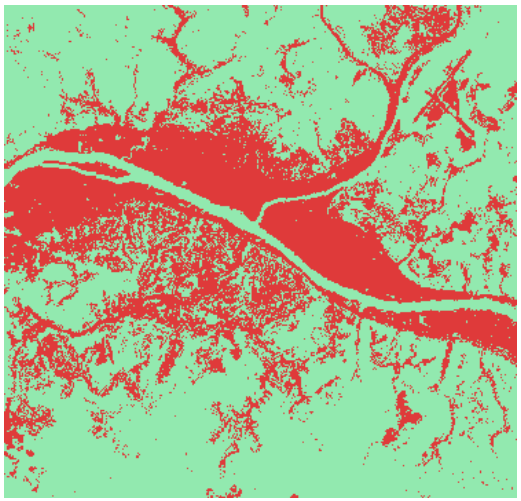
Avoid offensive color combinations…

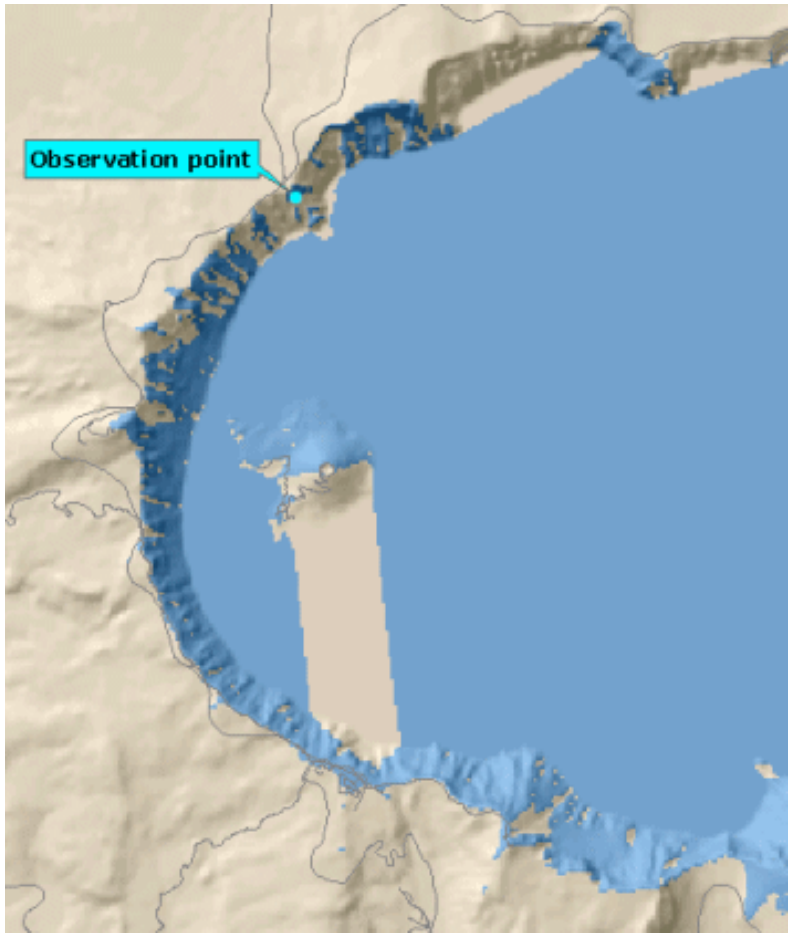


Binary Color Schemes

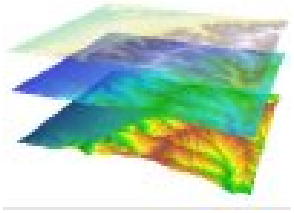
Binary schemes are a simple case of qualitative data with just two classes

Put more visual emphasis on one class if it is more important for the message of the map

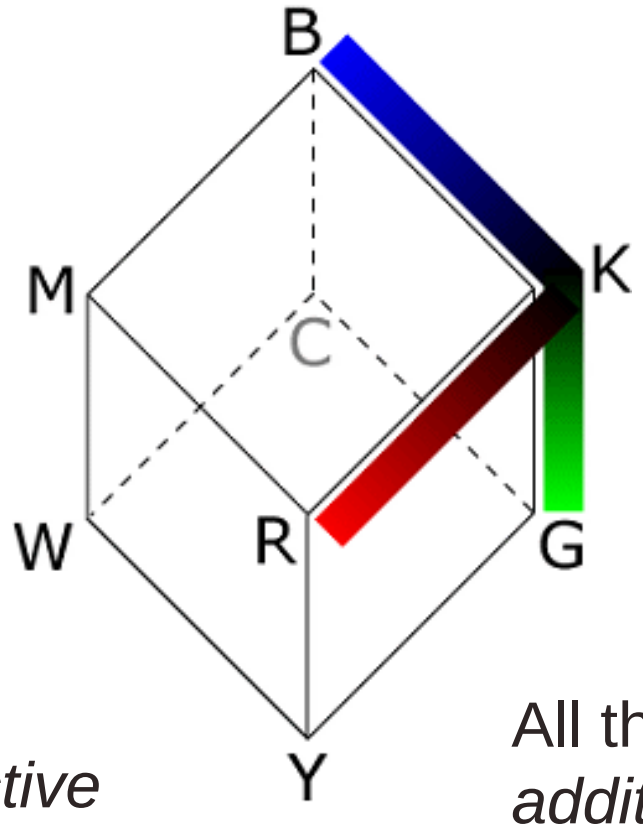




The Color Cube



Subtractive CMY

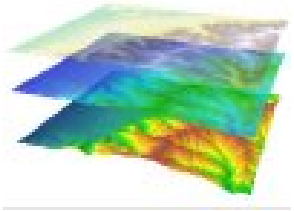


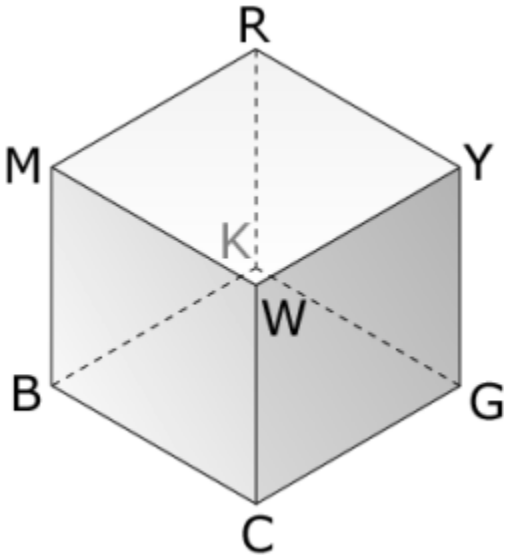
Additive RGB

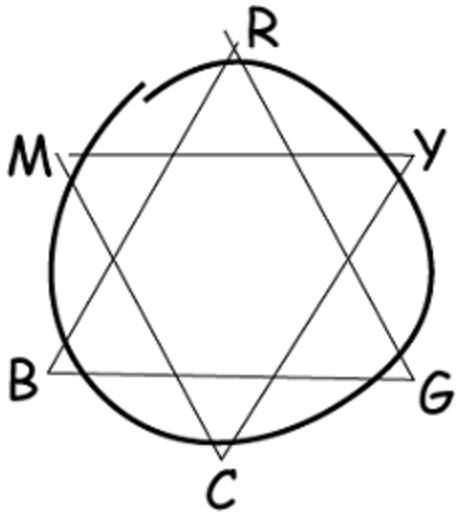
All the *subtractive* primaries are light colors

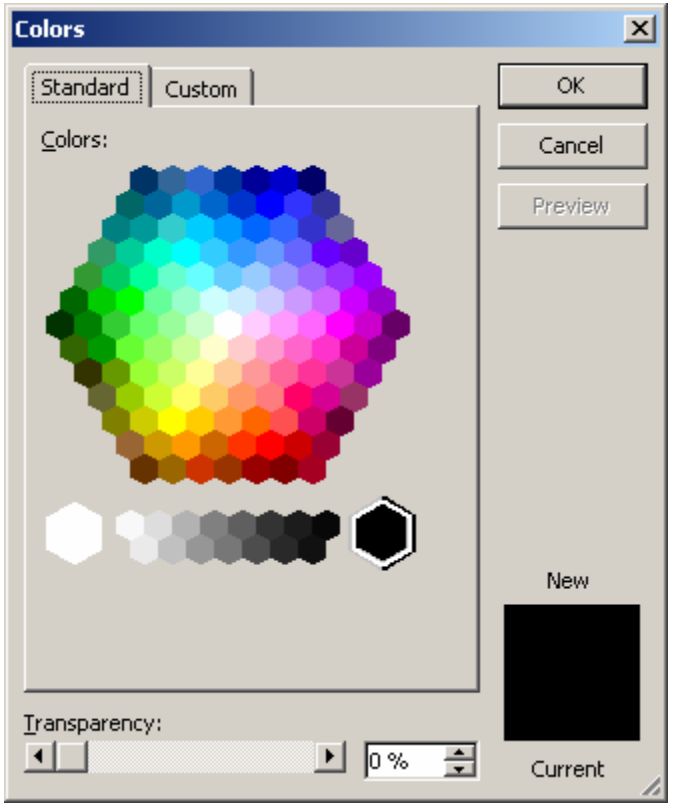
All the *additive* primaries are dark colors

Selecting Colors

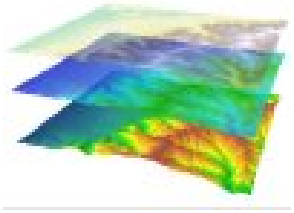






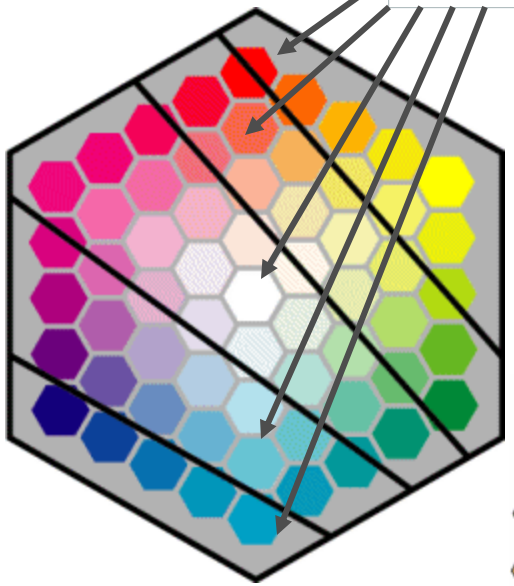


Colors for Colorblind

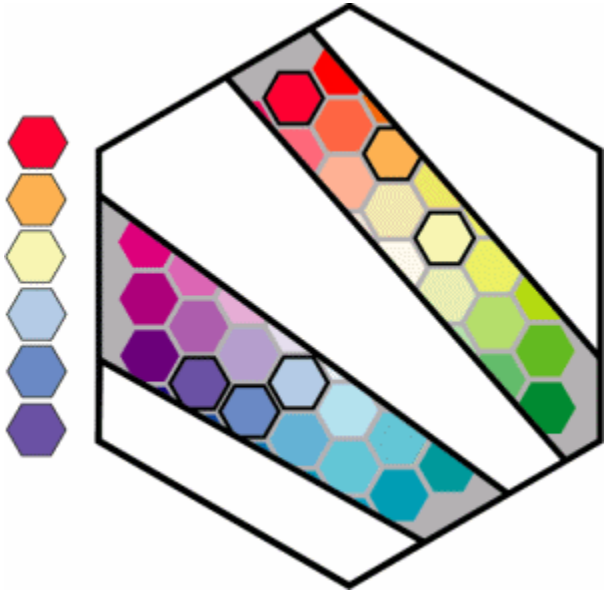


Good color combinations:

- red-blue
- red-purple
- orange-blue
- orange-purple
- brown-blue
- brown-purple
- yellow-blue
- yellow-purple
- yellow-gray
- blue-gray

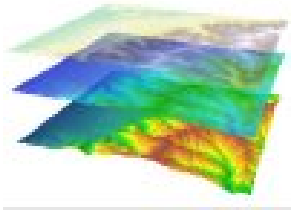


Choose colors two or more zones apart

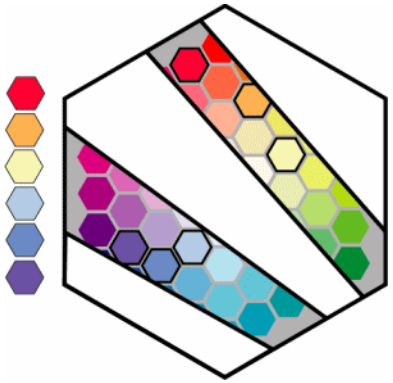


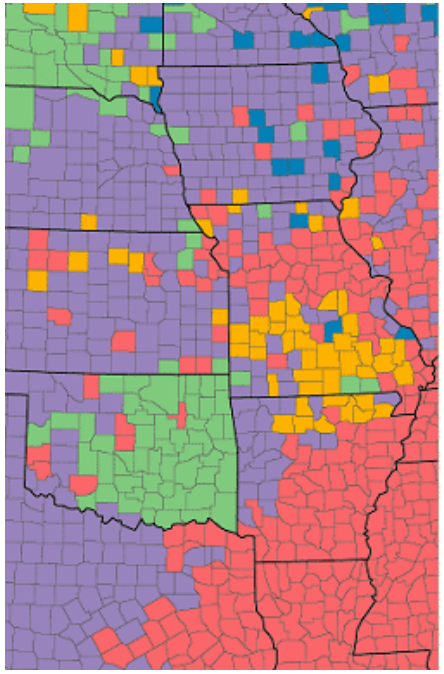
Choose pairs of hues from the list above and build a lightness sequence within each hue

Colors for Colorblind



Chose color pairs that are in separate color zones.

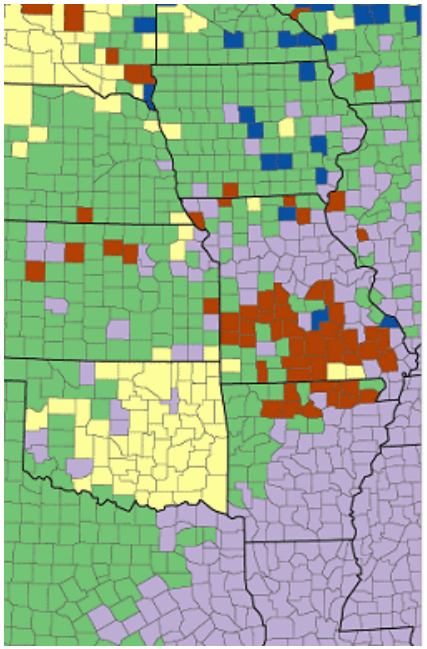




Minority group with highest percent of county population

Excludes White, not Hispanic

- Hispanic or Latino
- Black or African American
- American Indian and Alaska Native
- Asian
- Two or more races, not Hispanic or Latino



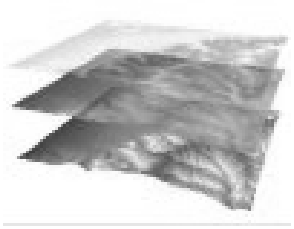
Minority group with highest percent of county population

Excludes White, not Hispanic

- Hispanic or Latino
- Black or African American
- American Indian and Alaska Native
- Asian
- Two or more races, not Hispanic or Latino

http://www.vischeck.com

Colors for photocopying

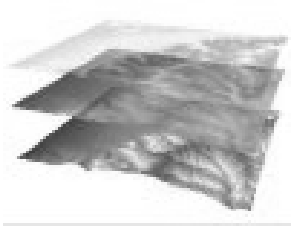


The key to making a color map that can be printed in black and white or photocopied is to include large differences in lightness between colors.

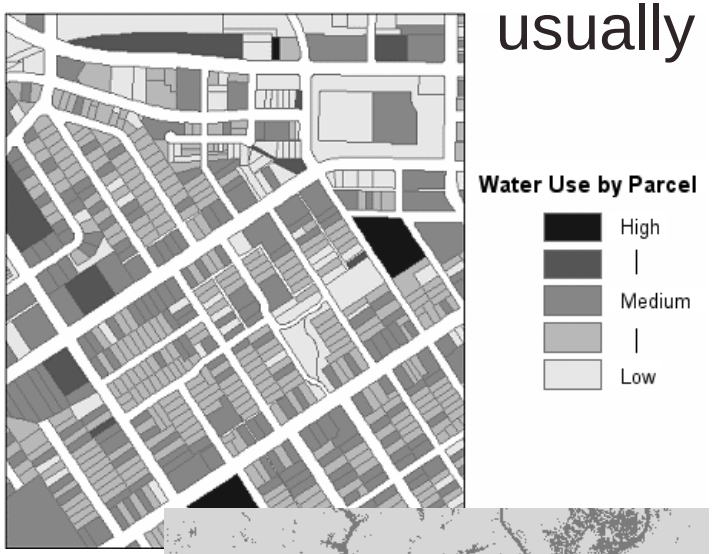
Useful process to test map for photocopying

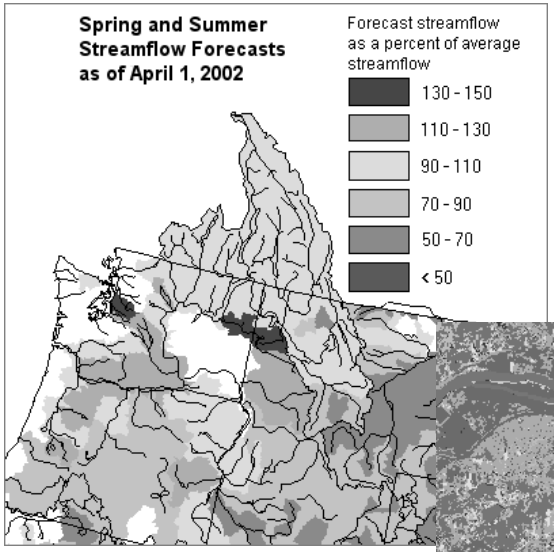
1. Print the map.
2. Copy it.
3. Darken and lighten map colors.
4. Print.
5. Copy.
6. Adjust map colors.
7. Repeat as needed.

Colors for photocopying

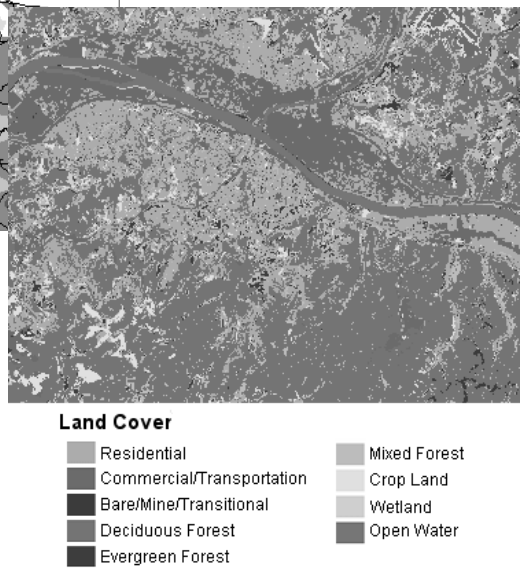


Sequential and binary maps usually do well



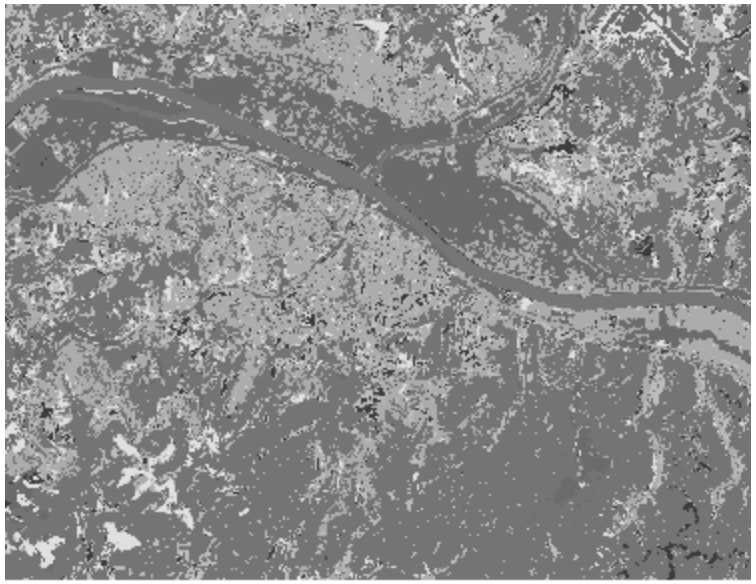


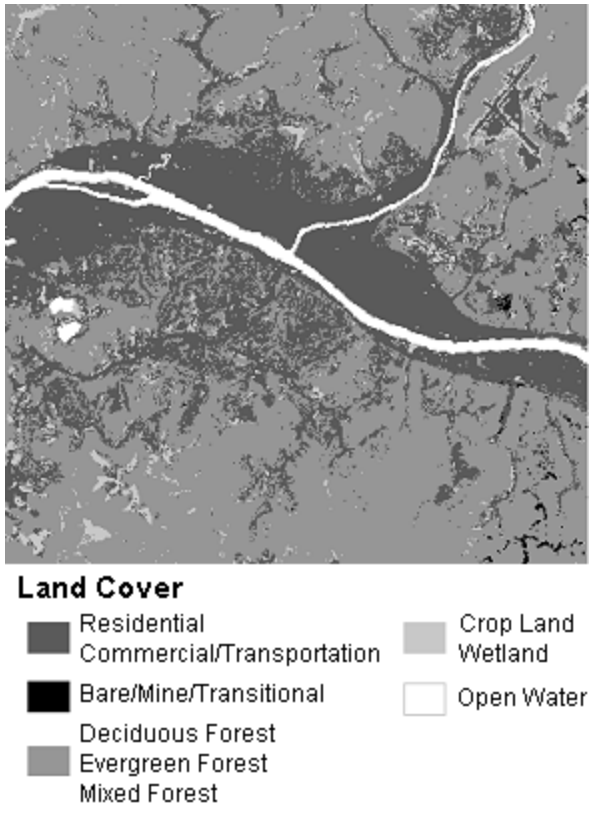
Divergent and qualitative maps often don't.



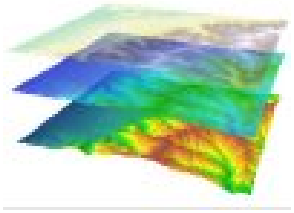
Colors for photocopying

The solution often requires redesign and simplification of the map





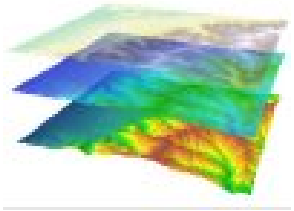
Colors in Context

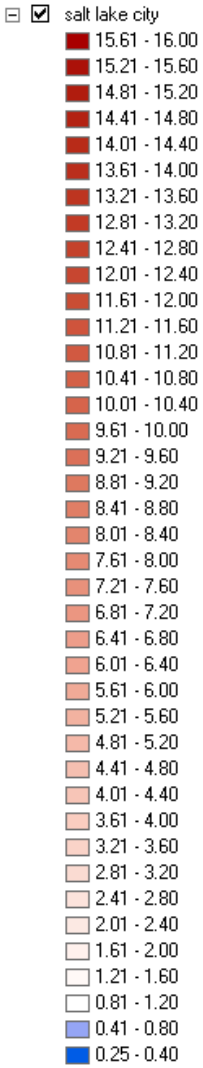


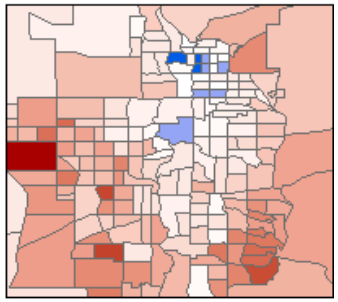
Colors on maps need to be distinguishable.

Some colors appear to change with different backgrounds

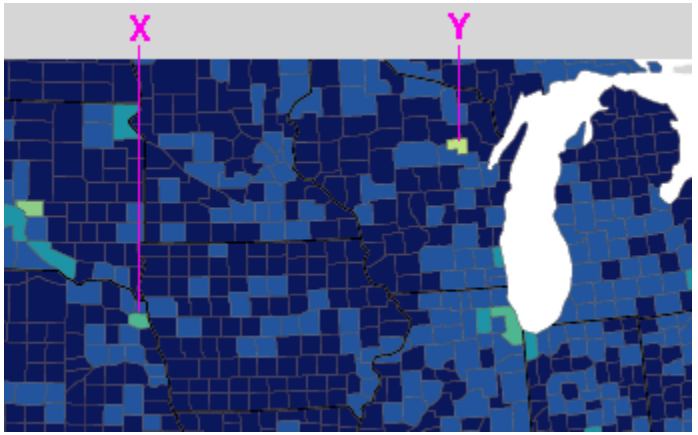
Colors in Context

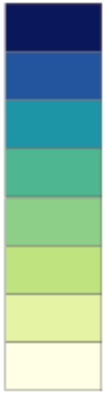


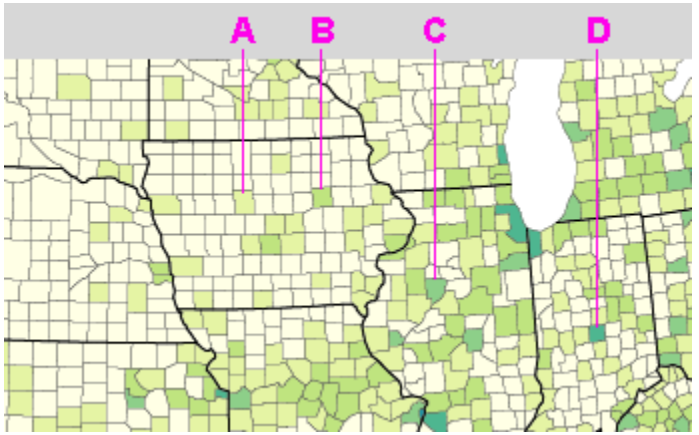




Avoid too many colors to relate to legend!







Symbology: Points

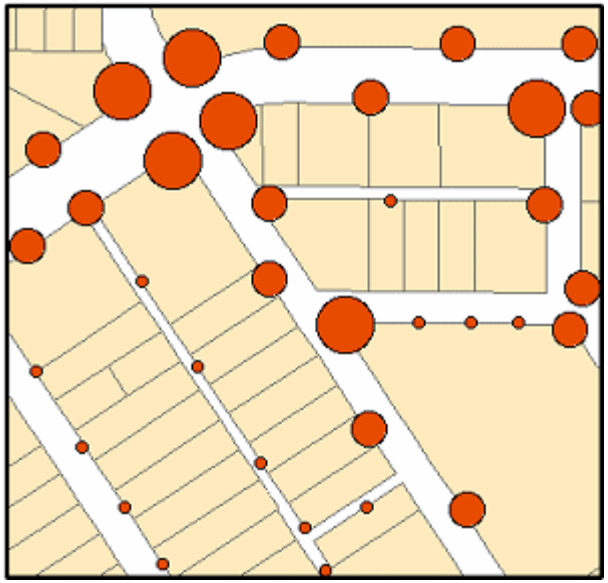
Symbol characteristics:

- Size
- Shape/ pictograms
- Angle
- Hue/lightness

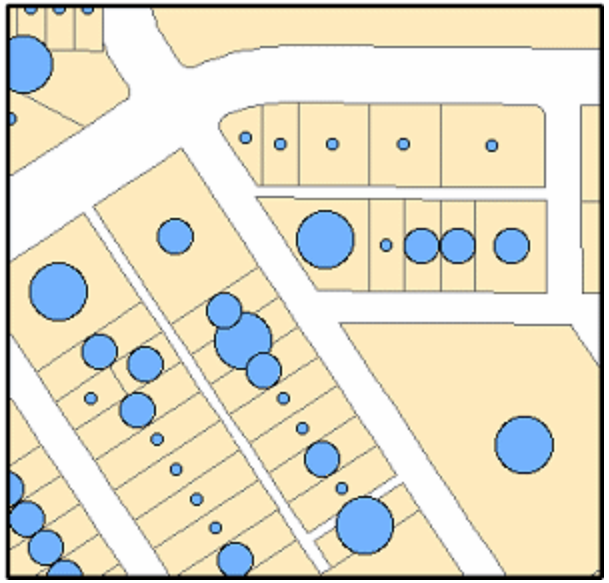
Symbology: Points

Symbol size:

Often used to show quantitative differences



Street lamp illumunation
(location and quantity)

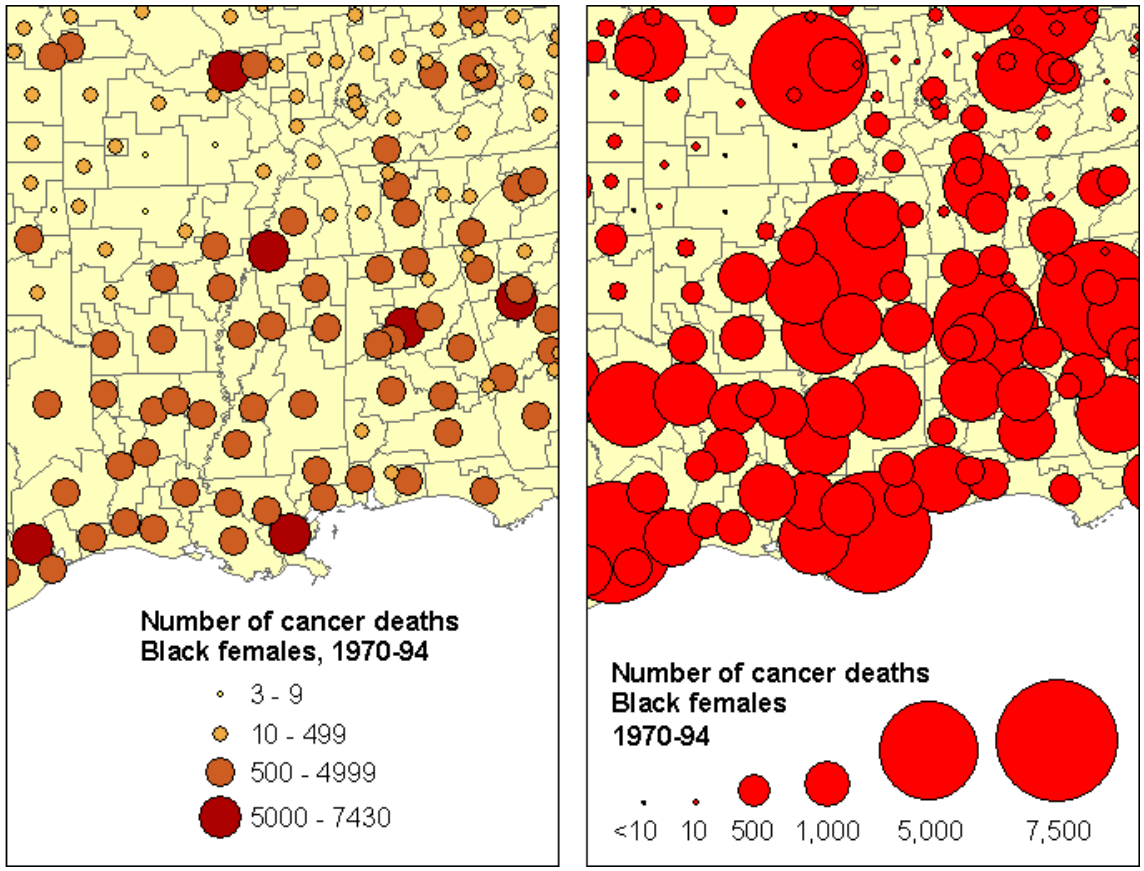


Household water usage
(quantity label)

Symbology: Points

Symbol size:

Graduated v. Proportional



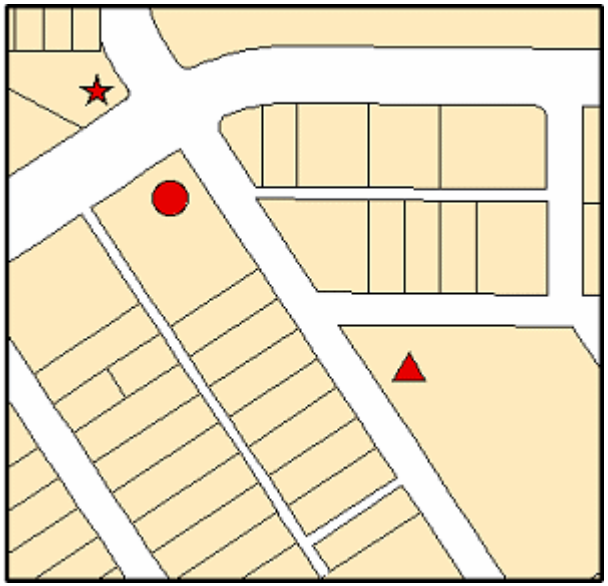
Graduated values indicate order

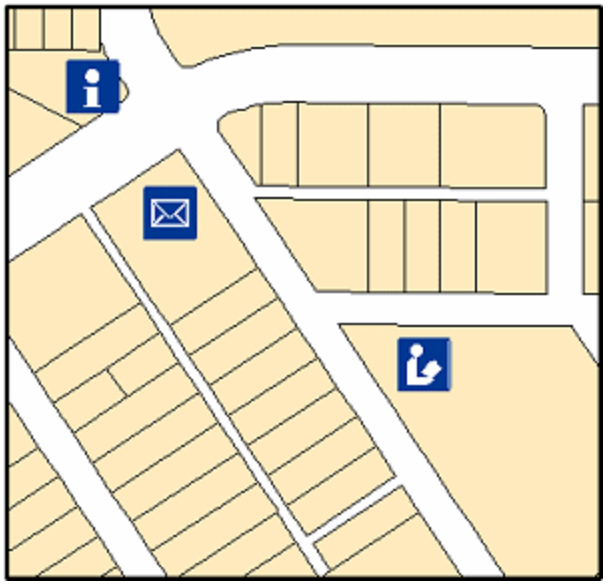
Proportional values indicate value or magnitude

Symbology: Points

Symbol shape:

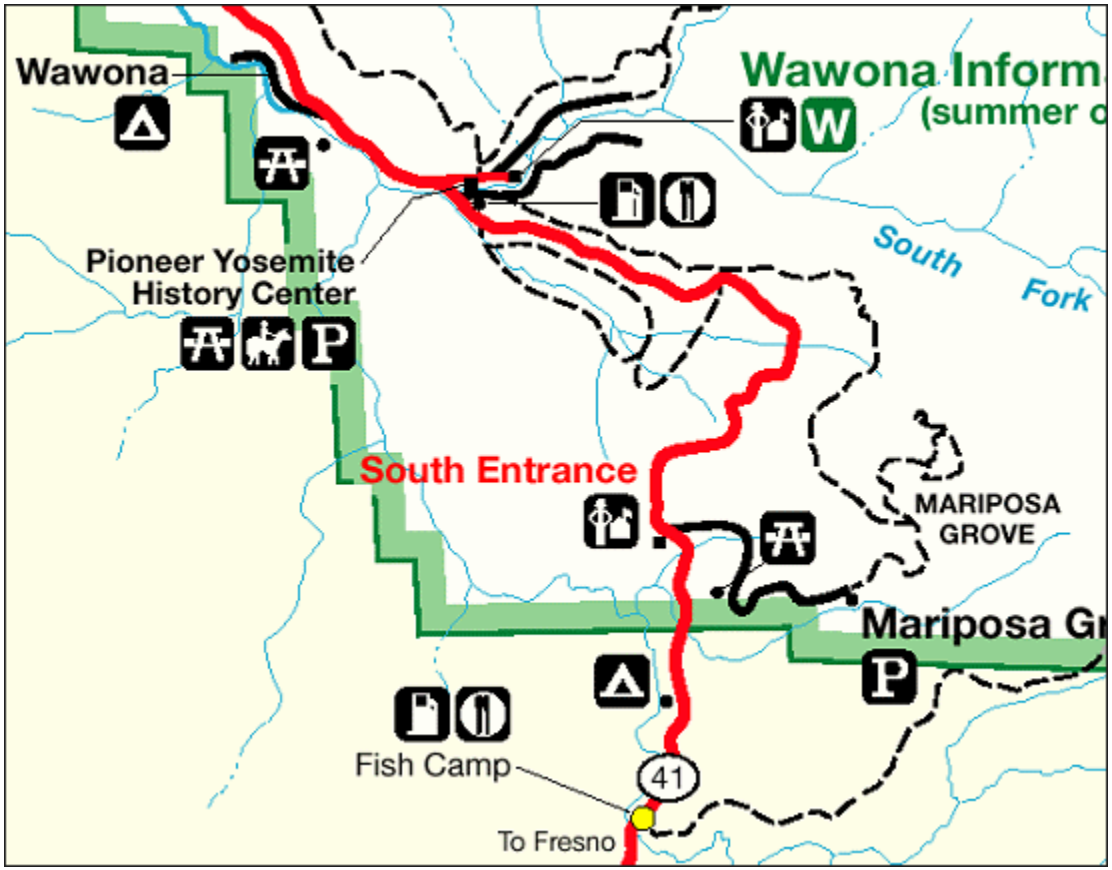
Often used to show qualitative differences



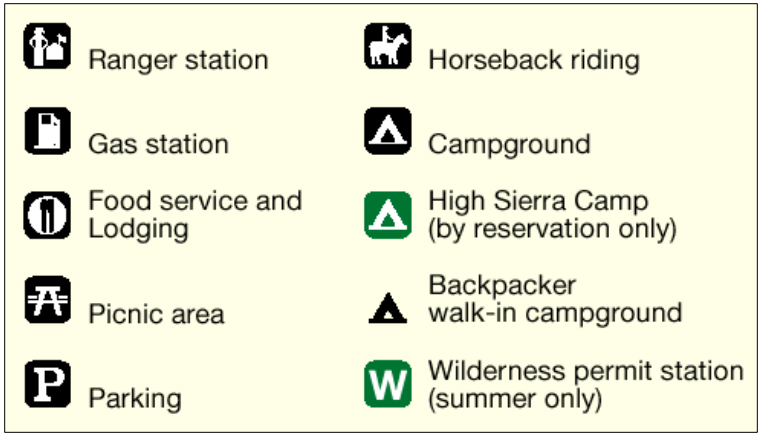


Symbology: Points

Pictograms:



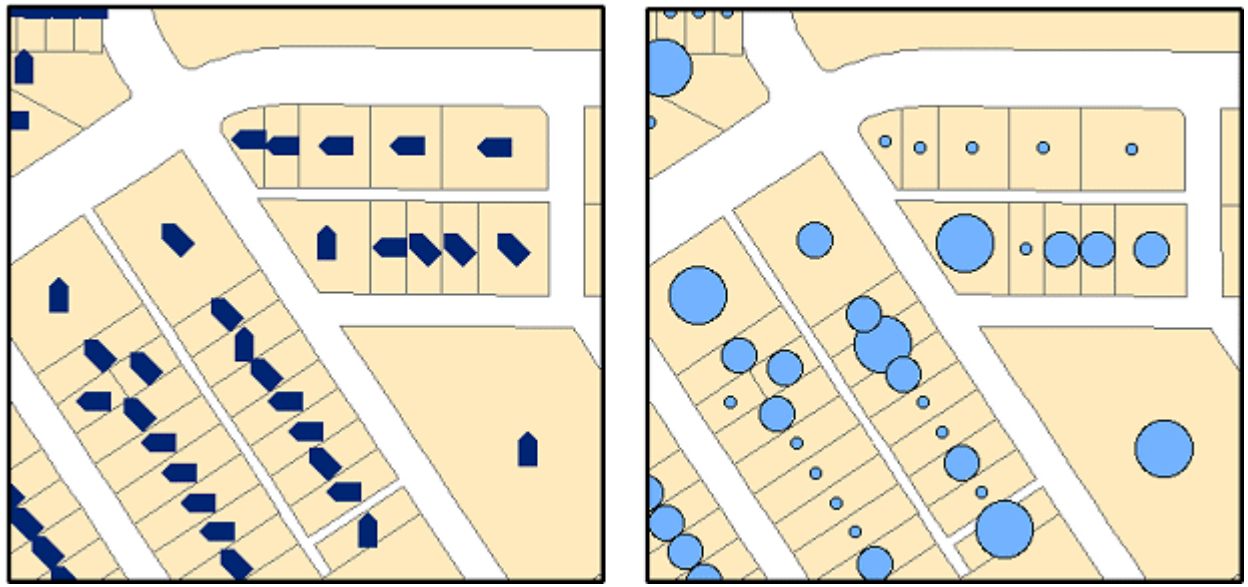
Enhance readability
Easy to translate



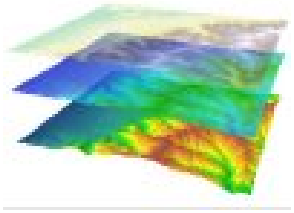
Symbology: Points

Symbol angle:

Often used to show orientation



Symbology: Lines



Line characteristics:

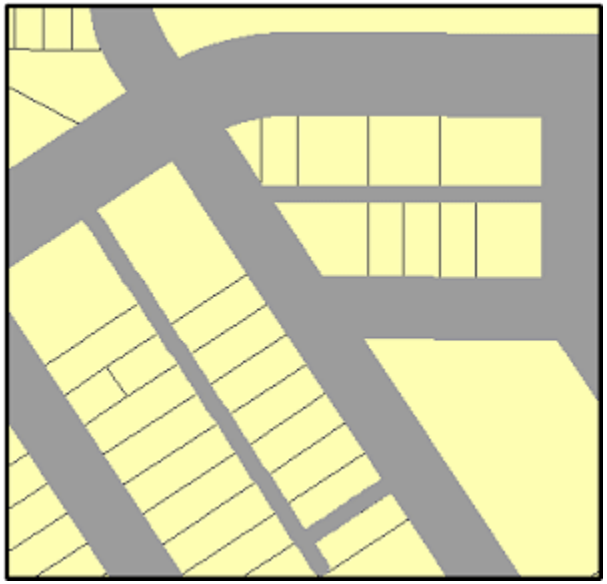
- Hue & lightness
- Size
- Separation
- Shape
- Arrangement
- Angle

Symbology: Lines

Line symbol size:

Size can be adjusted proportionally or gradually to show quantitative differences…

Number of lanes (graduated)

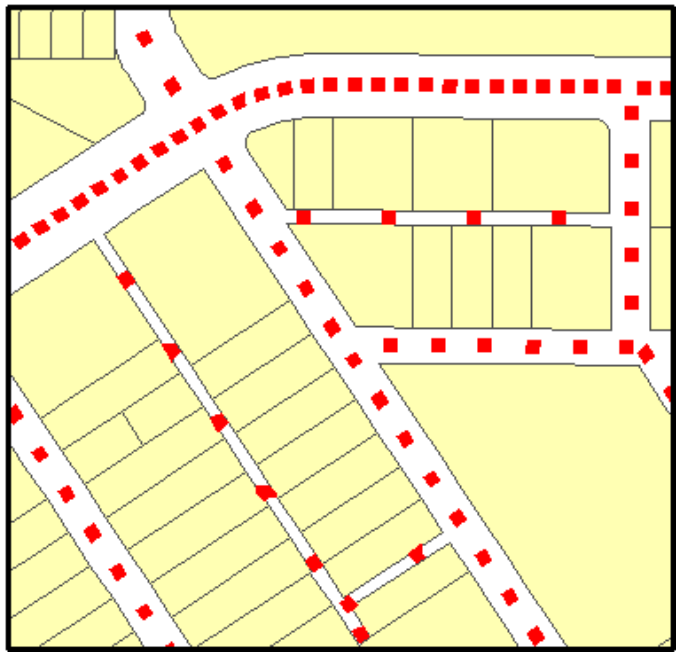


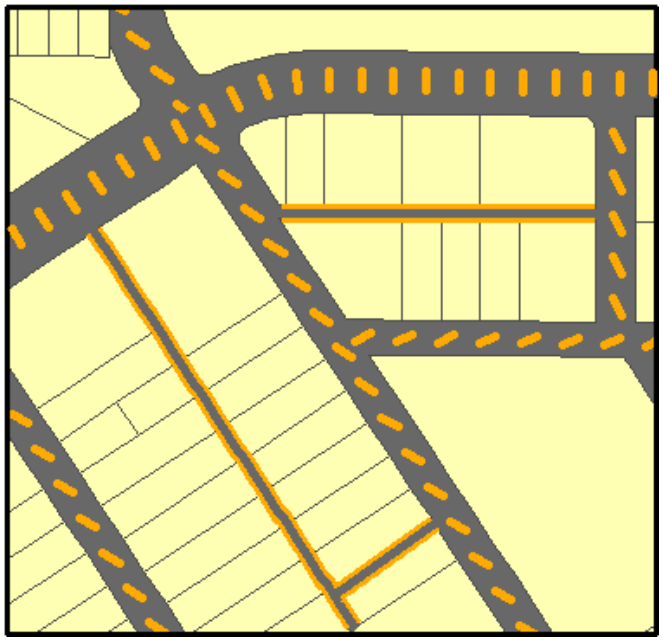
Traffic flow (proportional)

Symbology: Lines

Line pattern: *Dashing*

Symbols and separation can show qualitative differences in features. Separation and angle can also be used to show quantitative differences



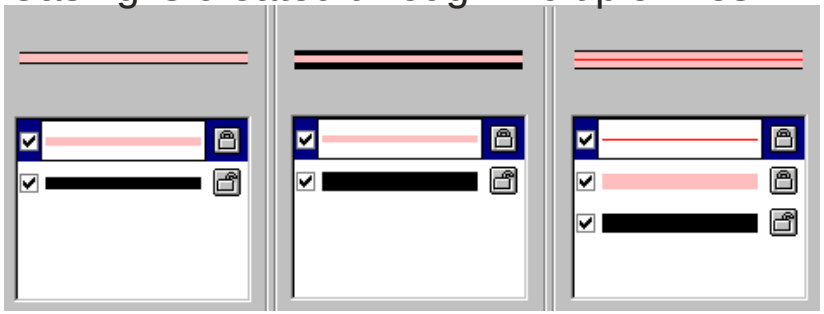


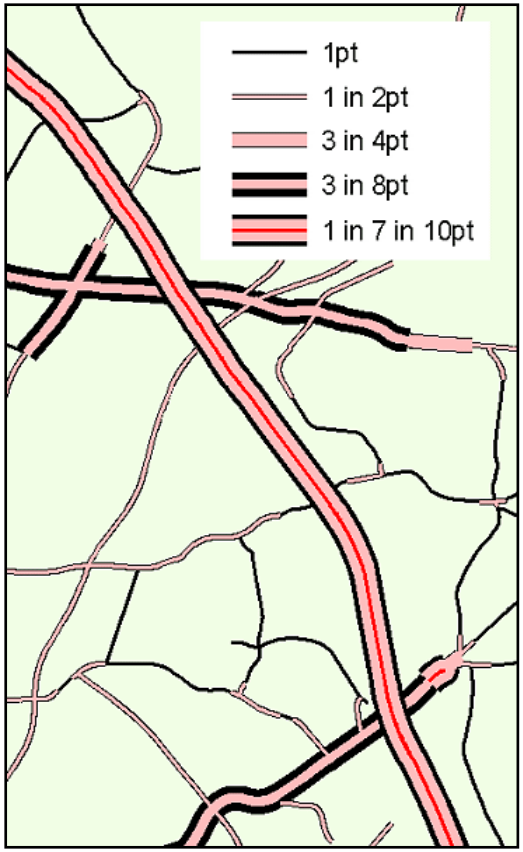
Symbology: Lines

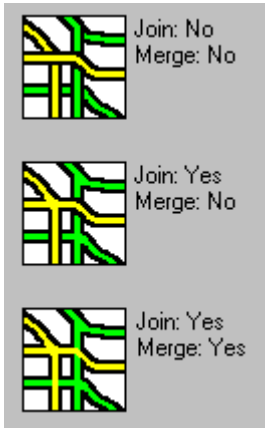
Line pattern: *Casing*

Casing can increase line visibility (like halos for text) without elevating its position in the map hierarchy.

Casing is created through multiple lines





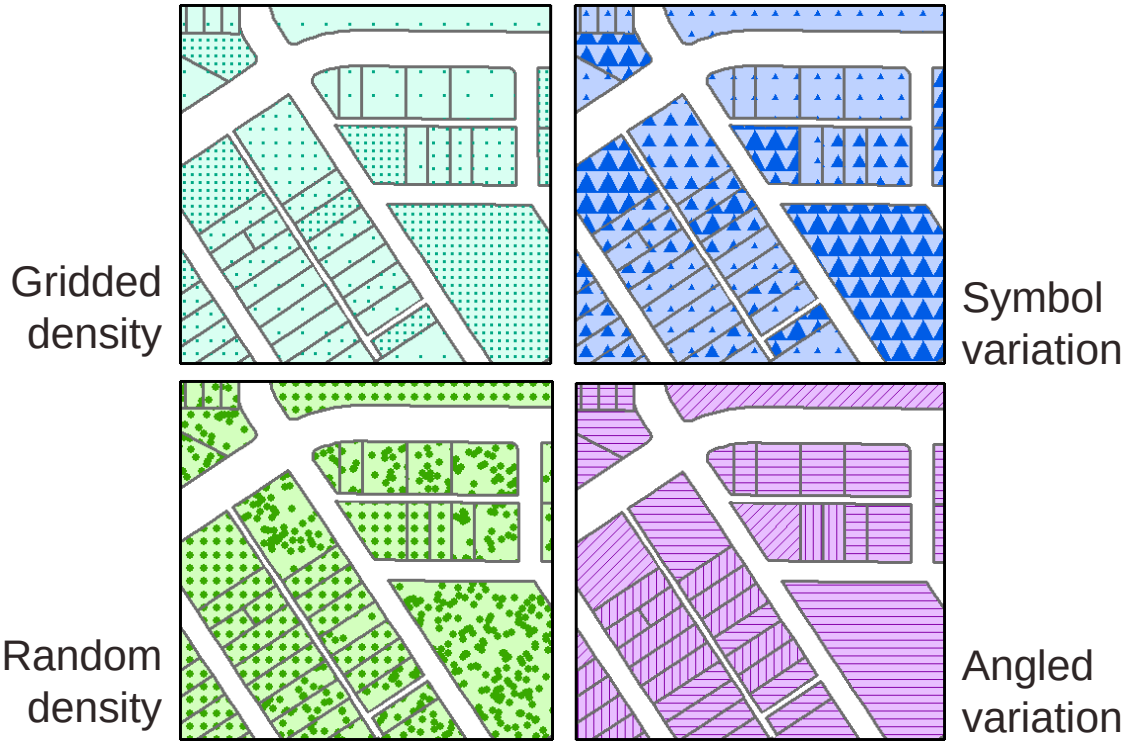


Join and Merge toggles in the Advanced Drawing Options settings control the way different cased line features intersect or break other lines.

Symbology: Areas

Area patterns can be literal or completely abstract.

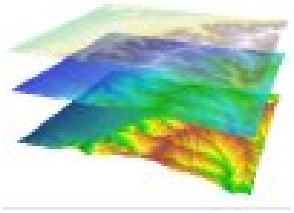
Use patterns and textures that adhere to the map's visual hierarchy and follow guidelines for color



Symbology: Areas

This map combines hue, lightness, arrangement, angle, separation, shape, and saturation to create high-contrast area patterns for different land uses.

Visual Variables



7 visual variables

- Hue
- Lightness
- Size
- Shape
- Shape
- Separation
- Arrangement
- Angle

x 3 types of features

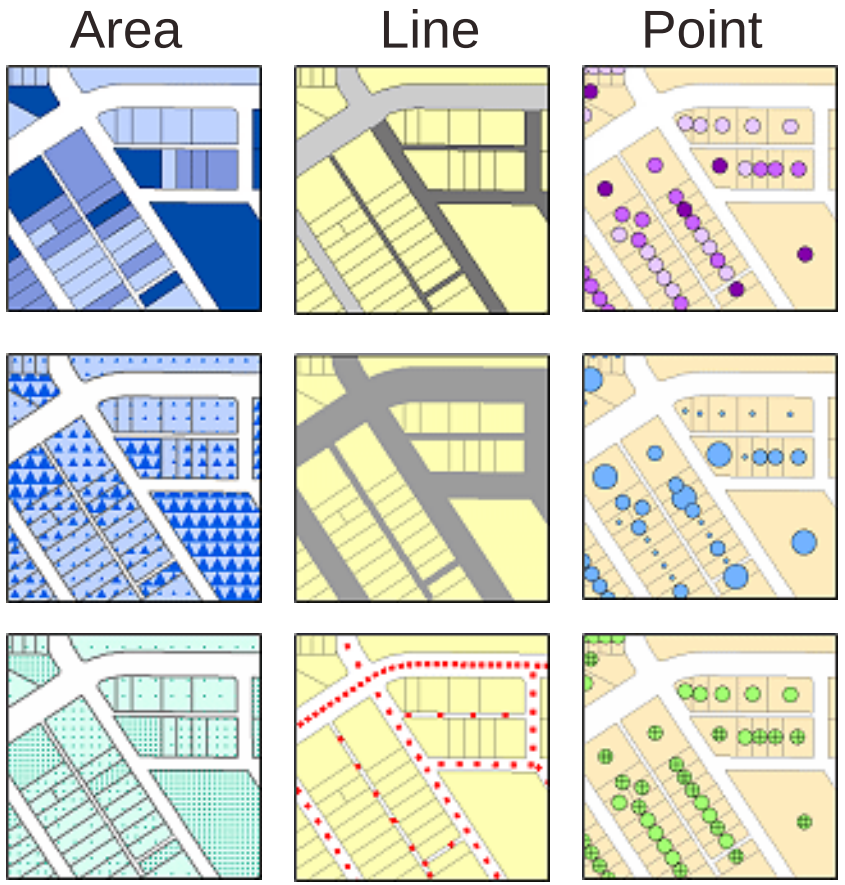
- Points
- Lines
- Areas

---

21 ways to vary symbols for representing mapped data!

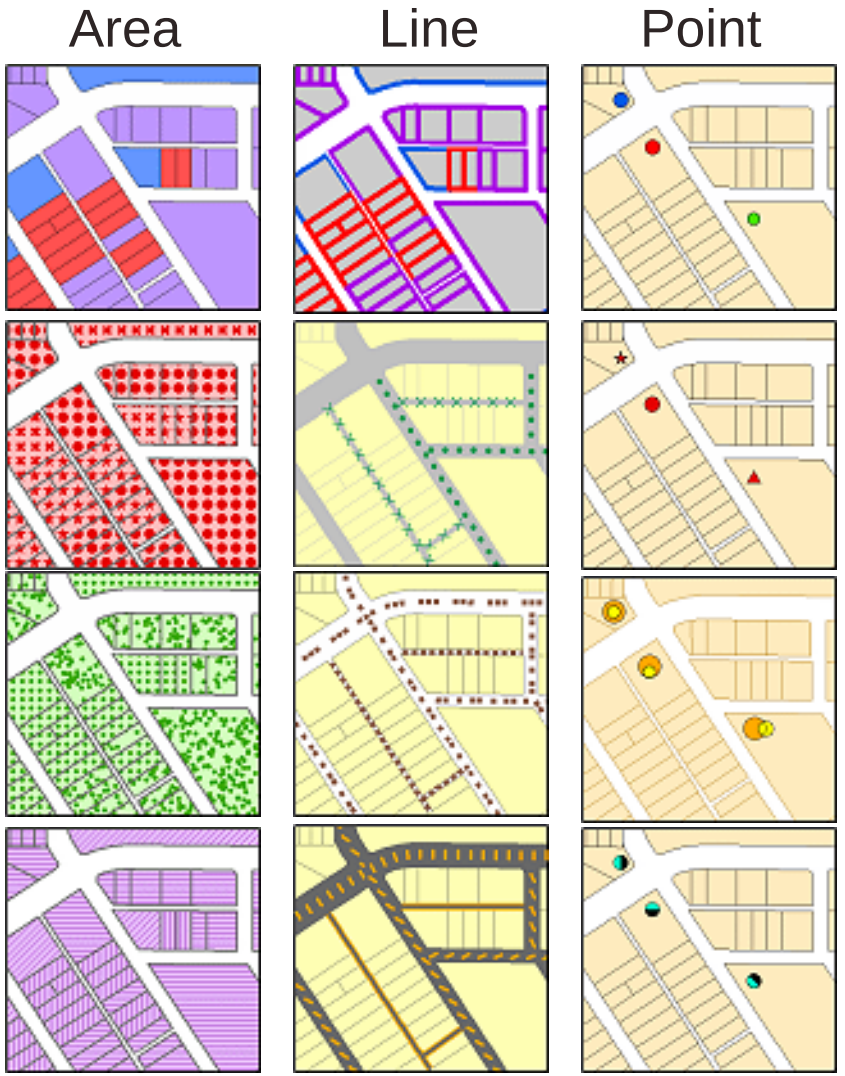
Visual Variables

Ordered data

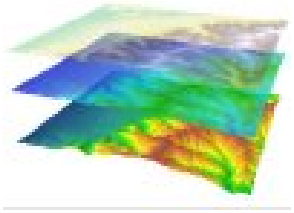


Visual Variables

Qualitative data



Symbology: Review

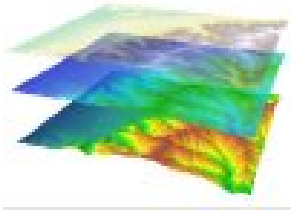


- Size, shape, and angle as well as hue and lightness are the primary visual variables used to create point symbols.

- Point symbols can represent discrete features such as hydrants or telephone poles, or they can represent attributes of area features. When point symbols are used to represent quantitative data values for areas, larger symbols represent higher data values.

- Hue, shape, and arrangement are used to represent qualitative differences in data values (different categories of features).

Symbology: Review



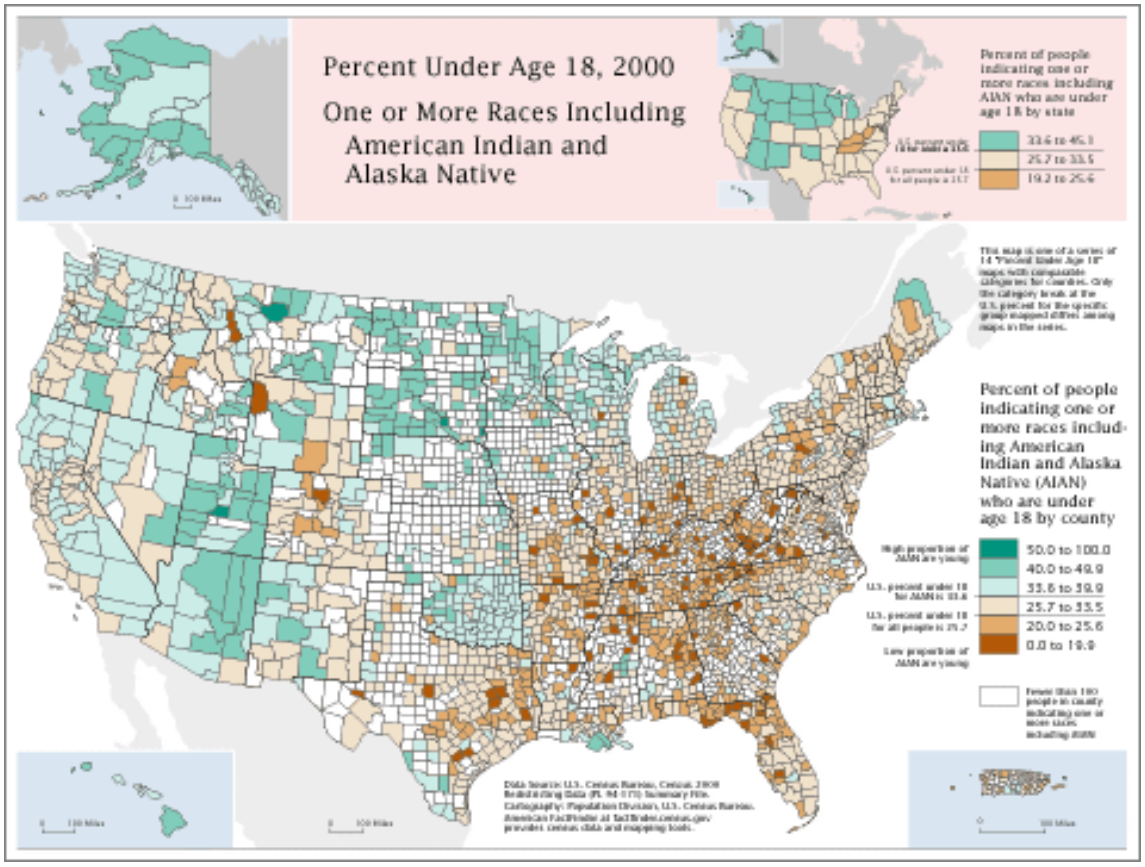
- Lightness, size, and separation are visual variables used to symbolize ordered data.

- Dashed and cased lines combine the visual variables of separation, shape, arrangement, and angle. Dashes add pattern to a line, while casing helps increase line visibility over multiple backgrounds.

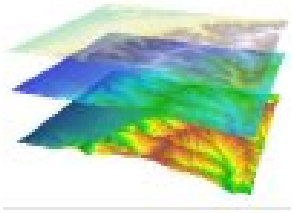
- Area patterns should clearly represent logical relationships within the data. Patterns with coarse and fine textures are used to represent hierarchy in data values. You can use shapes of elements within a pattern to indicate qualitative differences in data. Angle and arrangement can also be used with area patterns to indicate qualitative differences.

Putting it all together

How align map data and marginal map elements to create an informative, but not disruptive map layout.



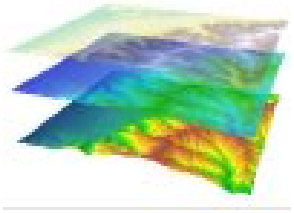
Putting it all together



GOALS:

- Clearly communicate the map content using hierarchy of detail.
- Refine labels so that spacing within and between lines of text conveys clear associations with other map elements

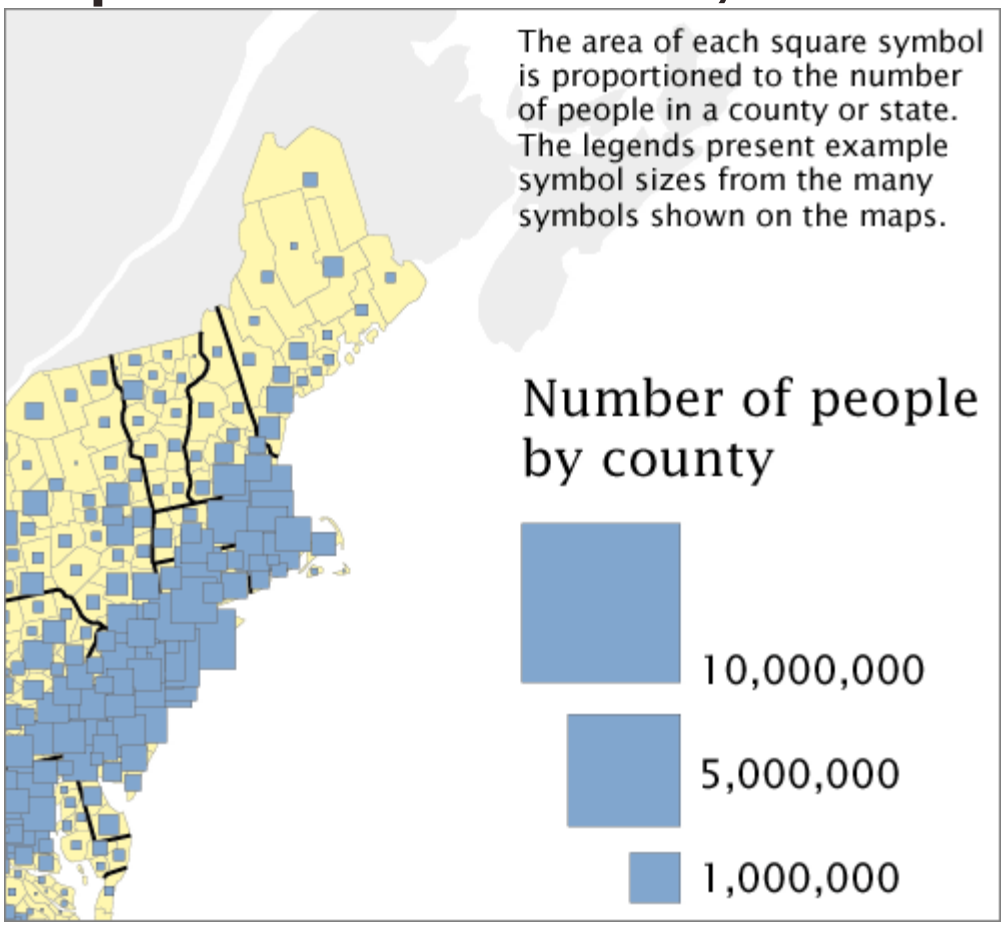
Putting it all together



Simple map…

Short title

Population Distribution, 2000



Note to add detail

Legend title elaborates

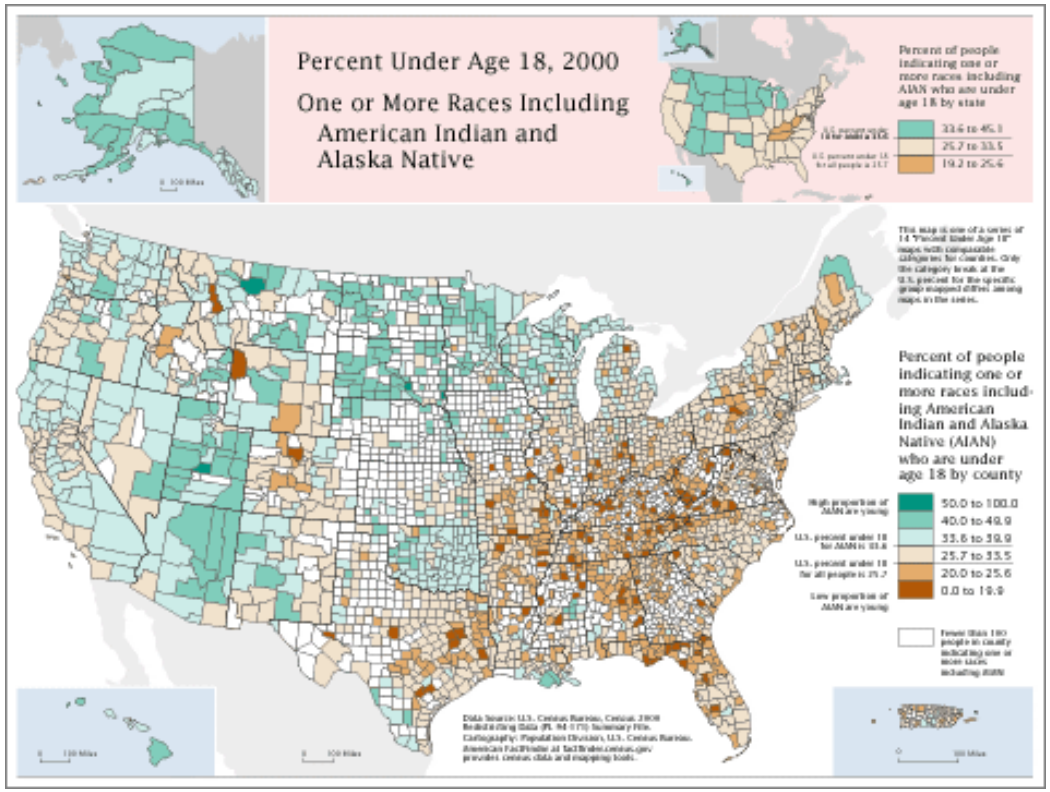
Map Titles

Include in legend

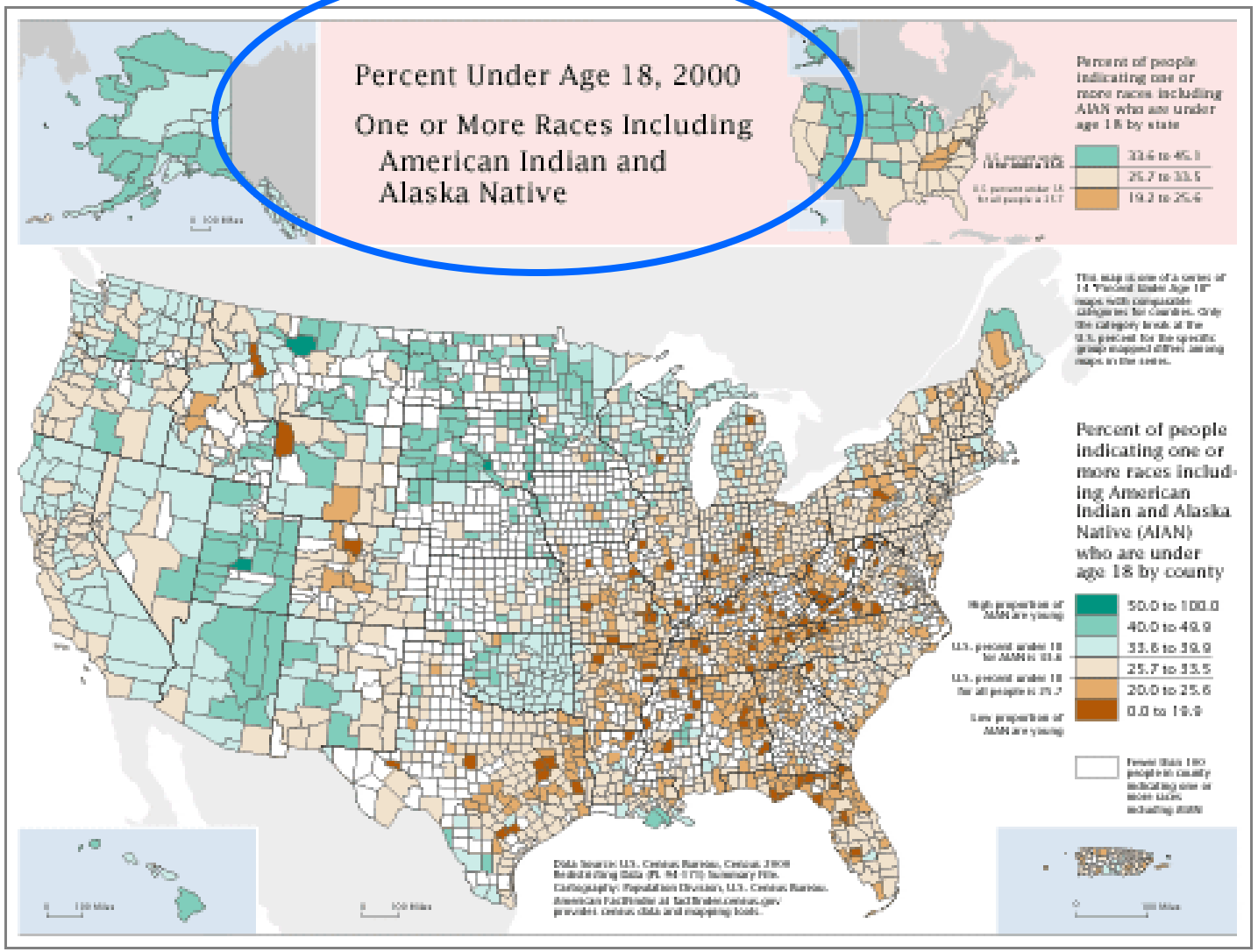
A map showing the distribution of the percent of people indicating one or more races including American Indian and Alaska Native who are under age 18 in 2000 by county in the United States prepared using Census 2000 Redistricting Data

It's obvious where…

Add as note

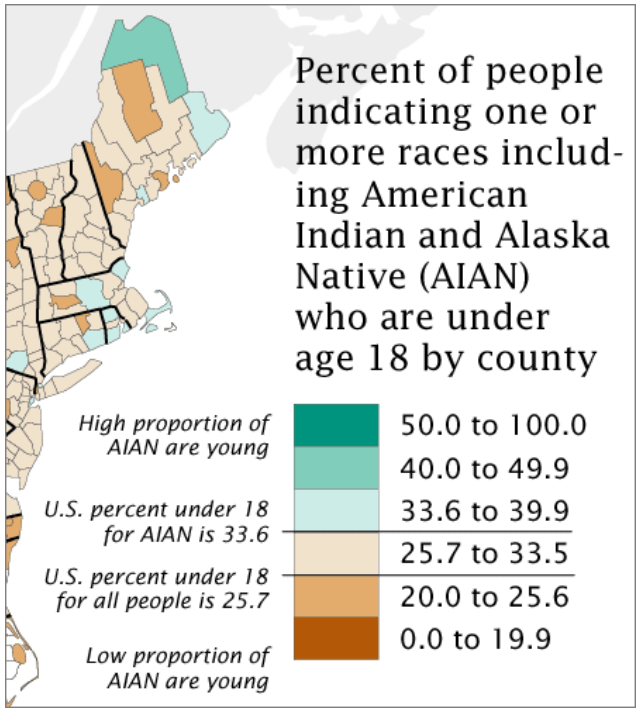


Map Titles

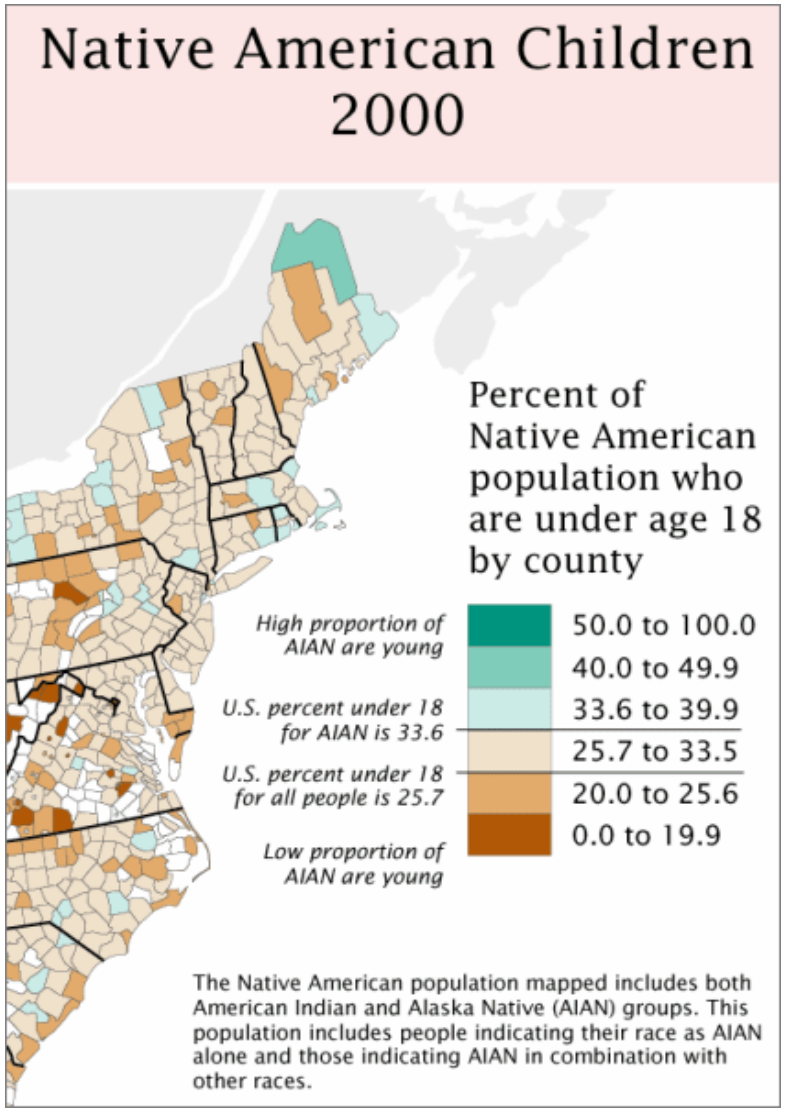

Percent Under Age 18, 2000
One or More Races Including
American Indian and
Alaska Native
Percent of people indicating one or more races including AIAN who are under age 18 by state
Percent of people indicating one or more races including American Indian and Alaska Native (AIAN) who are under age 18 by county
50.0 to 100.0
40.0 to 49.9
33.6 to 39.9
25.7 to 33.5
20.0 to 25.6
0.0 to 19.9

Map Titles

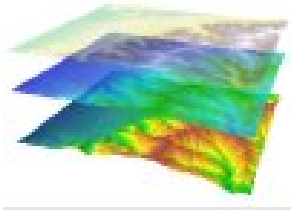
Titles can be simplified by adding text notes and detailed legends in the map



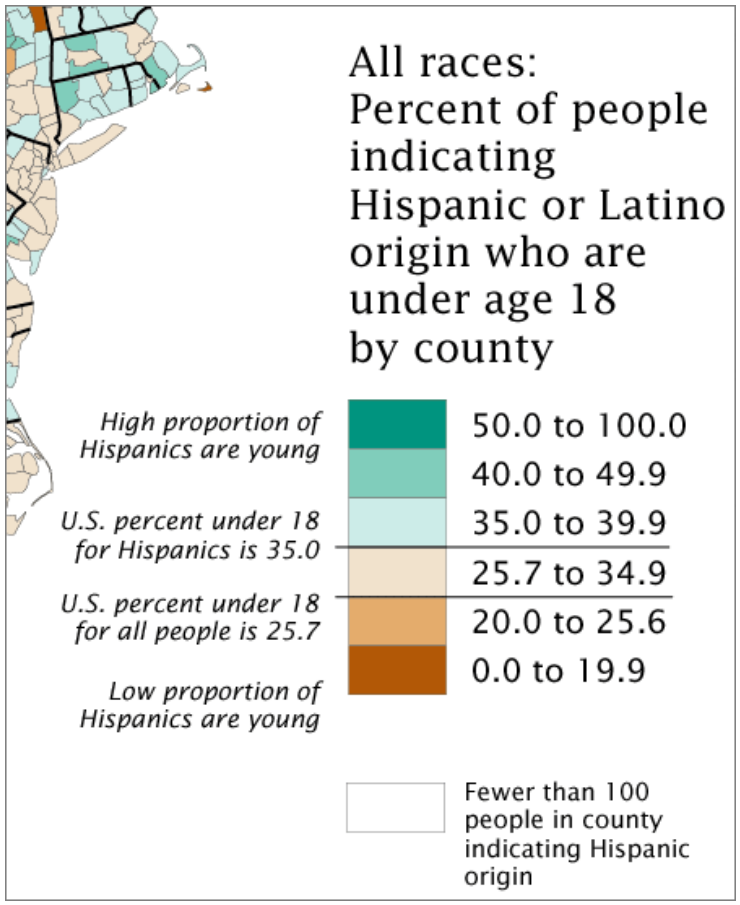
Notes should be low in the map hierarchy



Describing calculations



Describing the work used to derive the map is important but difficult to describe concisely.



"Percent of people indicating Hispanic or Latino origin who are under age 18 by county" ***wordy***

"Percent Hispanic under 18 by county" ***ambiguous***

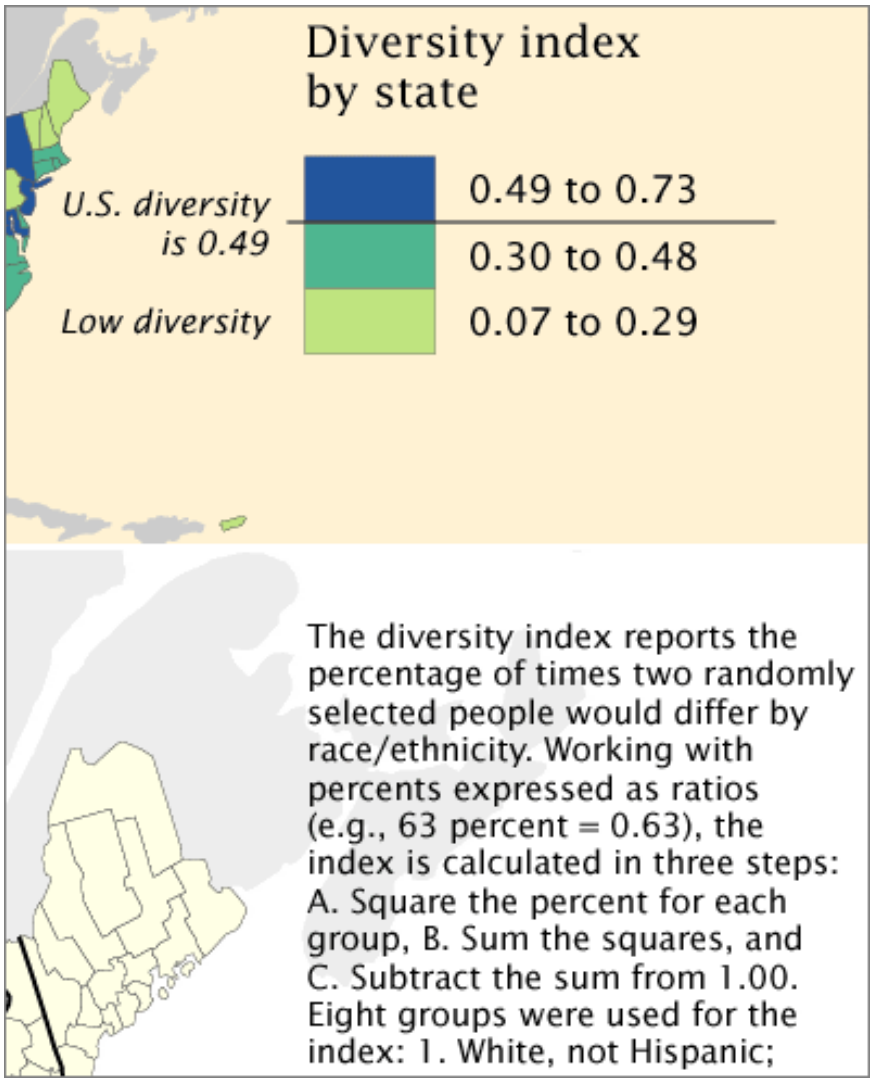
"Under 18 Hispanic percent by county" ***confusing***

"Percent Hispanic who are under 18 by county " ***good***

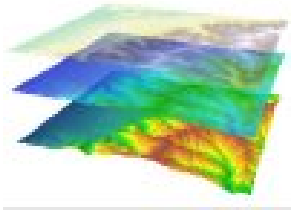
Describing calculations

Brevity is good, but coherence is essential. Readers will gain more from the map if they are sure what it represents.

If you have difficulty describing your calculations briefly, add a text note to your map layout.



Legend nuances



Some thought into the spacing and alignment of legend elements makes for a far clearer legend.

Transportation and Land Use Prince George's County, Maryland

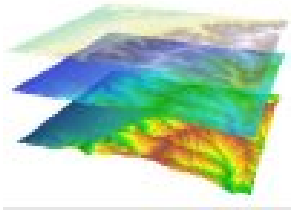
Land Use	Speed Limit
Urban	< 35
Institution	35, 40
Defense	45, 50
Parkland	55, 60
Water	

Transportation and Land Use

Prince George's County, Maryland

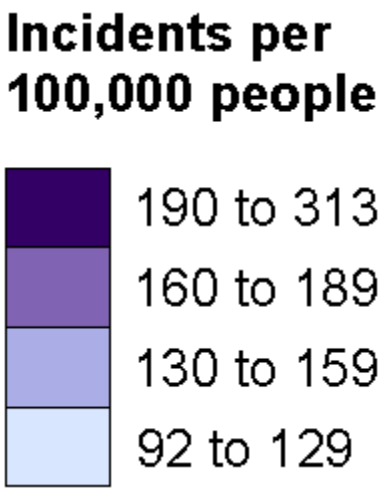
Land use	Speed limit
Urban	< 35
Institution	35, 40
Defense	45, 50
Parkland	55, 60
Water	

Legends



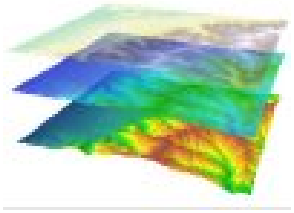
Choropleth maps

A thematic map in which areas are colored or shaded to represent the density of a particular phenomenon or to symbolize classes within it.



- Round numbers for breaks and within labels
- Increment labels (e.g., 0-10, 10-20 or 0-9, 10-19); this issue is linked to rounding
- Use the word "to" or a dash within ranges (this often depends on whether the data includes negative numbers)
- Label breaks between classes with single numbers rather than labeling class ranges
- Order classes with the highest numbers at the top (like the vertical axis on a graph) or at the bottom of the legend
- Label ranges with the actual values represented by the symbol, creating gaps between ranges
- Use the true maximum and minimum values in the data to label ranges or use statements such as "fewer than 100 people" or "more than 150 percent" for extreme ranges
- Add annotations to describe classes and assist map reading

Legends



Qualitative maps

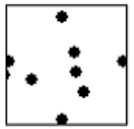
Housing characteristics

- under construction
- siding (wood, vinyl, aluminum)
- stone or brick
- vacant building

- Area symbols should present colors/patterns as close to as they appear on the map as practical.
- Use the same outline color and weight in the legend as in the map.

- Consider coloring the background of the legend to show colors as they appear on the map.
- Dot map legends should give example densities

Sample densities in people per square km



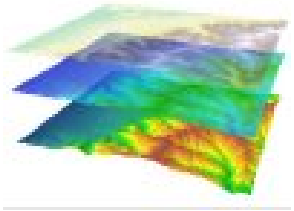
80

150

300

Each square represents 100 square km

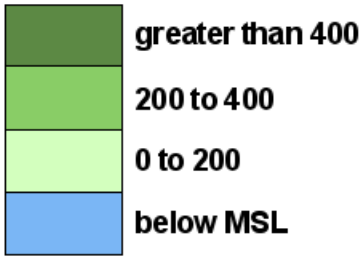
Legends



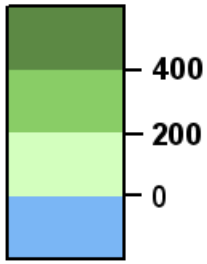
Isoline maps

Isoline interval is 200 meters

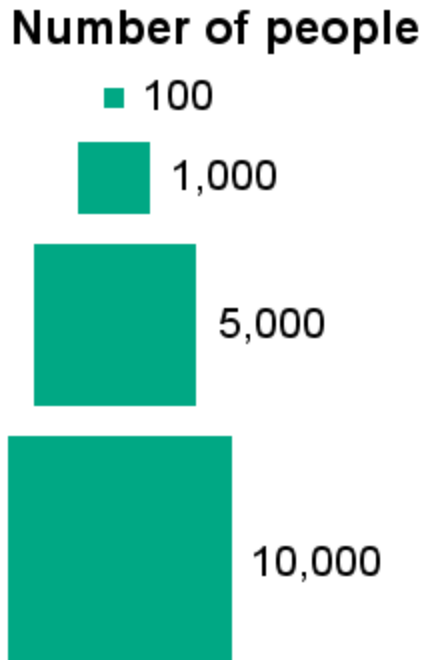
Elevation in meters
above mean sea level



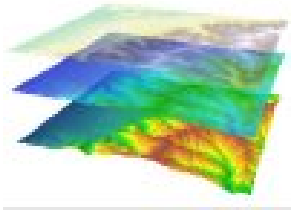
Elevation in meters
above mean sea level



Proportioned point

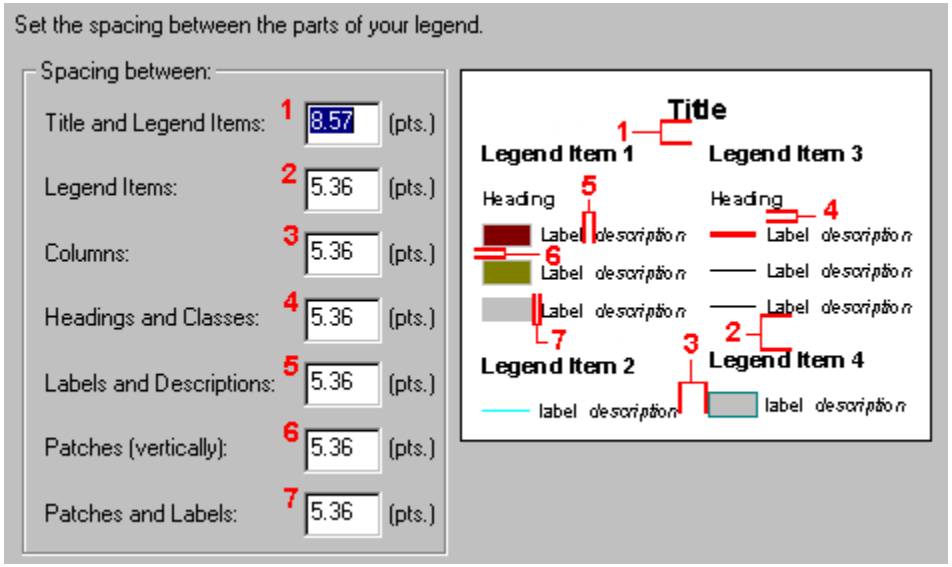


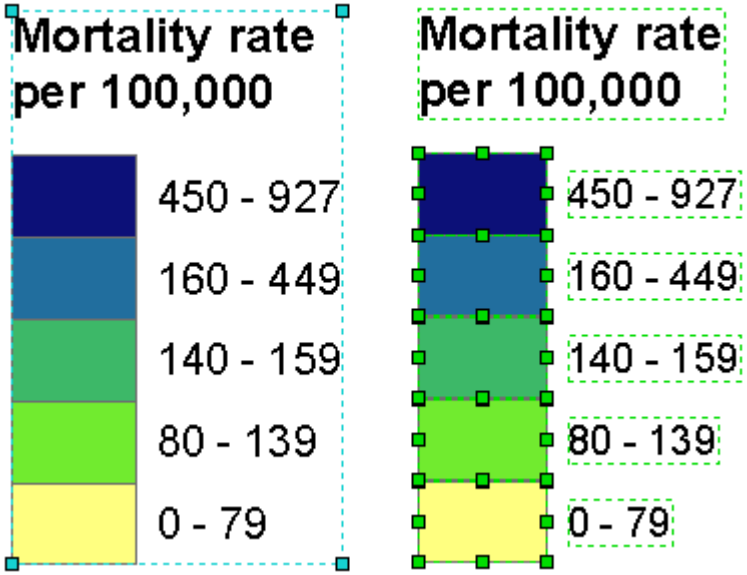
Legends



ArcMap and beyond

ArcMap allows some flexibility in the legend editor

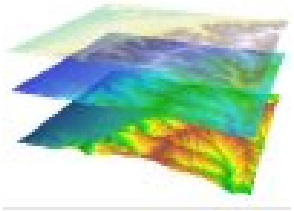




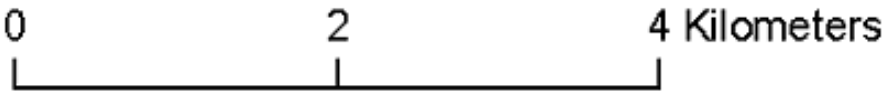
Converting the legend to graphics severs the ties to the data but adds much control over the layout.

Because the link is severed, this should be done at the end of creating the map.

Scale bars

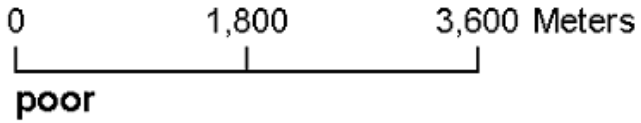


Graphic bar

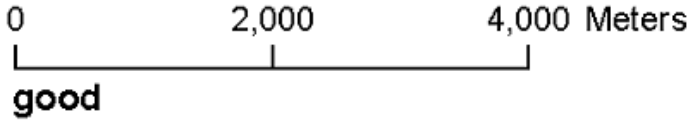


Verbal scale 1 centimeter equals 0.685 kilometers

Representative fraction 1:68,521



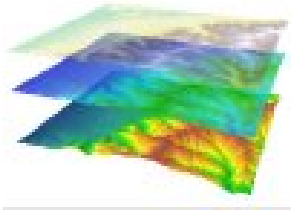
poor



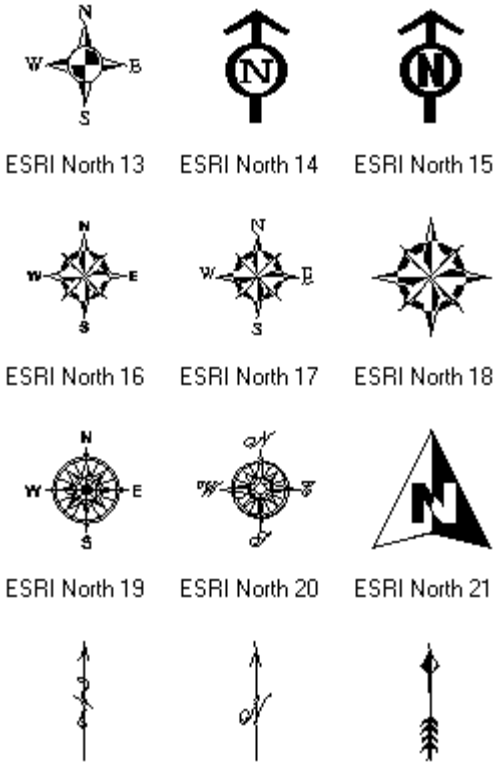
good

Use rounded numbers

Direction indicators

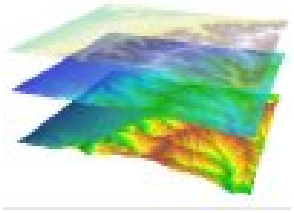


Compass roses



When direction is not constant, use a graticule

Summary



Cartography has many conventions and rules which often must be bent or broken.

The two most important rules, however, are:

- to keep your map on message by adhering to a sensible hierarchy of map elements, and
- always keep your audience in mind when choosing what to say and how to say it.