# CHAPTER SIX – OUTPUT

## INTRODUCTION

Mark Monmonnier's book, *How to Lie with Maps*, exposed how people and organizations overtly and intentionally misshaped map features to deceive.  The concept that underlies his entire book is that all maps lie—to some extent.  That statement is true.  As you read in Chapter 3, projections introduce shape, area, distance, and directional distortions.  In addition, all maps simplify the real world and thus lie by omission.  Map symbols exaggerate and minimize the extent of features.  These can all be considered lies.  Now, before you stop reading and discard maps as fiction, remember that all models of reality (paintings, literature, statistics, and photographs) are abstractions and thus lie to some degree and that omission and abstraction can lead to greater communication and understanding.  Simply put, maps aid in communication by emphasizing the location of features (and omitting many other features) to depict patterns across space.  As Monmonnier states, "A good map tells a multitude of little white lies; it suppresses truth to help the user see what needs to be seen" (1996, p. 25).

Some mapmakers radically distort features to enhance communication, and they can do this legitimately.  Perhaps the best example of manipulating the size and location of features is the London Underground map, which distorts subway line length and terminal location, but, in doing so, it enhances our spatial understanding of the subway system (see Figure 6.1).  Harry Beck, the map's creator, devoted his life to this user-friendly map.  He designed the map using only horizontal, vertical, and 45-degree lines that emphasized the relative position of terminals (connections) rather than adhering to strict spatial accuracy.  The distances from suburban terminals were shortened to give more map room for central city terminals.  He clearly understood that the traveling public perceived the network in terms of stops and transit line connections, not distance.  The map communicated these principals clearly, and it has been copied by transit lines across the world.


Figure 6.1:  London's Underground Map.  Image is courtesy of London Regional Transport, 1991.

This chapter broadly focuses on GIS output and more narrowly on maps and their design.  If accurate and clear communication is your goal, as it should be, you need to consider topics already discussed like projections and scale (Chapters 2 and 3) as well as subjects described in this chapter including symbolization, classification, generalization, and color.

## MAP COMMUNICATION

The International Cartographic Association (ICA) defines a map as "a representation, normally to scale and on a flat medium, of a selection of material or abstract features on, or in relation to, the surface of the Earth."  In other words, maps are an approximation, a model, a summary of the real world.

Maps communicate; they represent and help us organize knowledge by representing a portion of the Earth's surface.  They are created for transmitting spatial information to a map reader, yet most maps are improperly designed and do not communicate easily nor effectively.  This is not the fault of the map reader.  The fault lies with the cartographer that makes the map.  To design better maps, consider the cartographic communication process with its four stages (see Figure 6.2):  1) Real World, 2) Selection, 3) Generalization, and 4) Map.

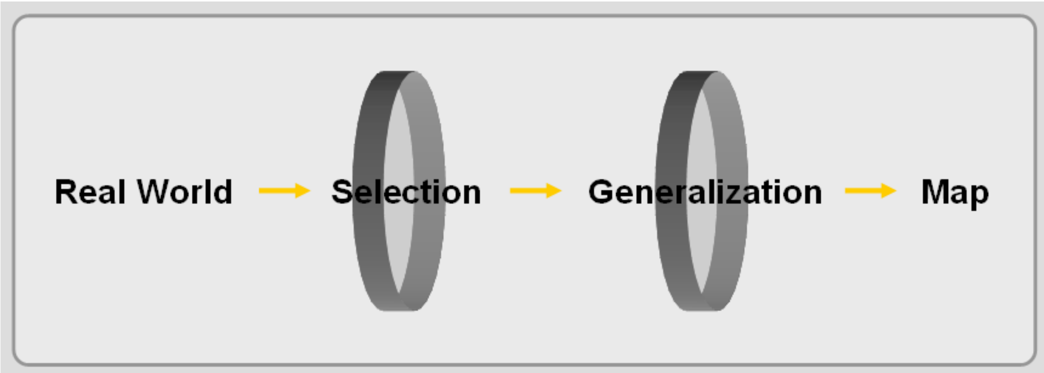


Figure 6.2:  Cartographic communication process.

***Real World***

As described in Chapter 1, the world is too complex for direct analysis and understanding, so we create models of the world by selecting and generalizing some of its features.  Imagine, however, if we could record the world's infinite detail on a map.  Lewis Carroll, author of *Alice in Wonderland*, described such a detailed map in *Sylvie and Bruno Concluded*.  In this fantasy, a Professor explains to another how his country's cartographers experimented with ever-larger maps.  The Professor states, "And then came the grandest idea of all!  We actually made a map of the country, on the scale of *a mile to the mile!"*  “Have you used it much?” the other person enquired."   No, says the professor, “It has never been spread out” … “the farmers objected: they said it would cover the whole country, and shut out the sunlight!  So we now use the country itself, as its own map, and I assure you it does nearly as well.”

In reality, the "country itself" is a poor replacement for a map.  If we could use the real world as our guide, then we would not need maps.  Every map selects and generalizes the world's features, and these little "white lies" help maps communicate.

***Selection***

Maps are selective.  You determine what should be, and equally important, what should not be included on your map.  If features do not aid your map's purpose, nor orient the map reader, eliminate them. There must be a reason for the presence of every feature type.  Guiding your selection process should be two essential considerations: the map's purpose and its scale.

What is the purpose of your map?  What are you trying to get across?  Who is your audience? Addressing these questions helps you determine how much detail should be placed on your map. Selecting too many types of features obscures your map's primary purpose.

Scale is the relationship between distances on the map (or screen) and corresponding distances in the real world.  It is a major factor in determining which features are selected and which are omitted.  Ask yourself, how is the map going to be presented to your audience?  Will it be on an 8 ½" x 11" piece of paper, a 3" x 3" portion of a newspaper, or through a data projector onto a screen?  The physical size of the presented map largely dictates the amount of detail that can be displayed on the map.  The chosen scale affects not only the selection of features but also the degree of their generalization.

***Generalization***

Geographic data and detail are without limit.  If you are flying high above a city, you will see certain features that define the city's overall shape and its major neighborhoods.  As you descend into a neighborhood, the homes, streets, parked cars, and sidewalks become clear.  Descend into a backyard and you see a pool, a vegetable garden, chairs, and a redwood deck.  Dogs and cats are visible.  Pull out a magnifying glass and investigate the redwood deck's grain to see its color, pits, splinters, and undulations.  To capture all of the real world's features and their detail, you would need an infinitely large database and an infinite amount of time.

The features you select need to be generalized, but how much detail should they have?  Map size being equal, large-scale maps that depict features in a small area can have more detail.  Here are several generalizing tasks to make map reading easier and more effective:

1. *Smooth* features. For example, take some kinks out of a river or a road. Beck's London Underground map (Figure 6.1) smoothed and straightened subway routes, which made the network more intuitive to map readers.
2. *Abstract* features. Detail catches the map reader's eye. Abstraction removes detail. Remove the detail of a city's street to a single line. For example, represent the library's actual footprint with a black square.
3. *Aggregate* features. Some features may be lumped together to deemphasize them. For example, represent several school buildings with a single symbol.
4. *Exaggerate* features. While smoothing, abstraction, and aggregation seek to deemphasize features, exaggeration places greater emphasis on the feature. If it is important for the purpose of your map, enlarge the feature.
5. *Displace* features. Sometimes features need to be moved, perhaps slightly, to accentuate them and make the map more visually pleasing and intuitive. For example, Beck moved London's train stations.

The primary role of maps is to communicate, and this is impossible without selection and generalization. Still, people have difficulty reading maps. If you find maps easy to read, it is partly due to your familiarity with maps and their conventions. Once you understand these conventions, map reading becomes easier and reinforces that understanding.

Conventions, a form of abstraction, are signs and symbols that allow people to read maps. Cartographers rely on conventions for good cartographic communication. Some conventions are almost universally understood like the use of blue for a river's line work and to fill a body of water. Most adults comprehend that water is symbolically represented by blue. Even on maps with text in foreign languages, you can distinguish water based largely on color. Lines on a road map are another example. They are easily understood as roads even though they have no width, lanes, curbs, or gutters.

Universal examples, however, are rare. Culture and profession influence how one interprets conventions. For example, red, which symbolizes danger (traffic lights and fire for example) and anger in Western countries stands for courage, happiness, success, and Communism in China. The greatest number of conventions, however, comes from professional associations, which have developed complicated formal and informal symbols. For example, geologists use both solid and dashed lines with associated symbols to infer normal faults, strike-slip faults, thrust faults and their associated characteristics like foliation, bedding, and lineation.

### *Maps*

Maps are the product, the output, of the cartographic communication process. There are several types of maps, usually divided into two categories: general purpose and thematic. General-purpose maps show the location of roads, rivers, institutions, and land covers. Thematic maps depict particular economic, social, demographic, political, or environmental themes like population density, age distribution, political party preference, income, or malaria. The discussion below describes some of the most frequently used thematic maps and includes some conditions for each of their use. It might be helpful to review the portion of Chapter 2 on data types (including levels of measurement) before reading this section.

### *Dot Density Map*

Thematic dot maps use dots or points to show a comparative density of features over a base map (see Figure 6.3). The dots are all the same size. Most dot maps are vector based and usually do not originate from point layers. They derive their dots from values stored in polygon layer attribute fields. Each polygon's attribute value dictates the number of dots displayed across the polygon feature. For instance, if one of your polygon features had a value of 2,223 cattle and you decided to represent 500 cattle with one dot, the map would have four dots randomly draped over the polygon.

*Data type:* Interval

*Feature type:* Polygon (sometimes point)

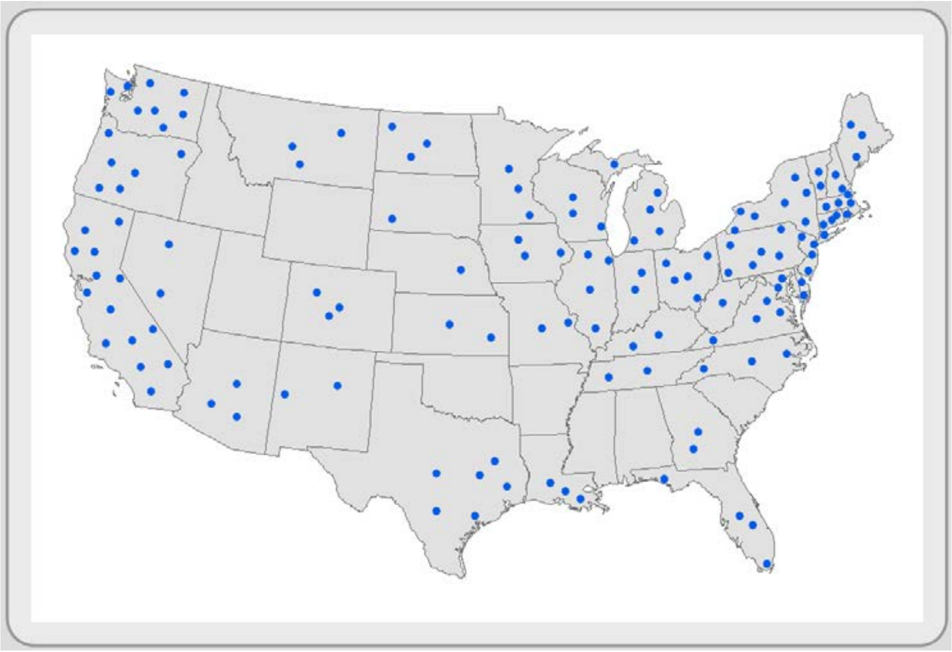

Figure 6.3: Dot density map.

### *Isoline (Isarithmic) Map*

Isoline maps use continuous lines (sometimes called isolines or contours) to reference differences across a continuous surface. Lines connect places that have the same value. They require at least ordinal data, but generally use interval or ratio data.

Two types of isoline maps exist: Isometric maps contain absolute data, which is based on scanning the entire surface. Remote sensing imagery is a good example. Isometric maps are largely raster-based due to the continuous nature of the layer. Isopleth maps, the second type, create continuous data from discrete data. In other words, it derives a continuous surface from multiple known locations where measurements were taken (locations in a point layer) (See Figure 6.4). Temperature and rainfall maps are good examples. These maps are both raster and vector based.

*Data type:* Interval or Ratio (sometimes ordinal)

*Feature type:* Raster or point

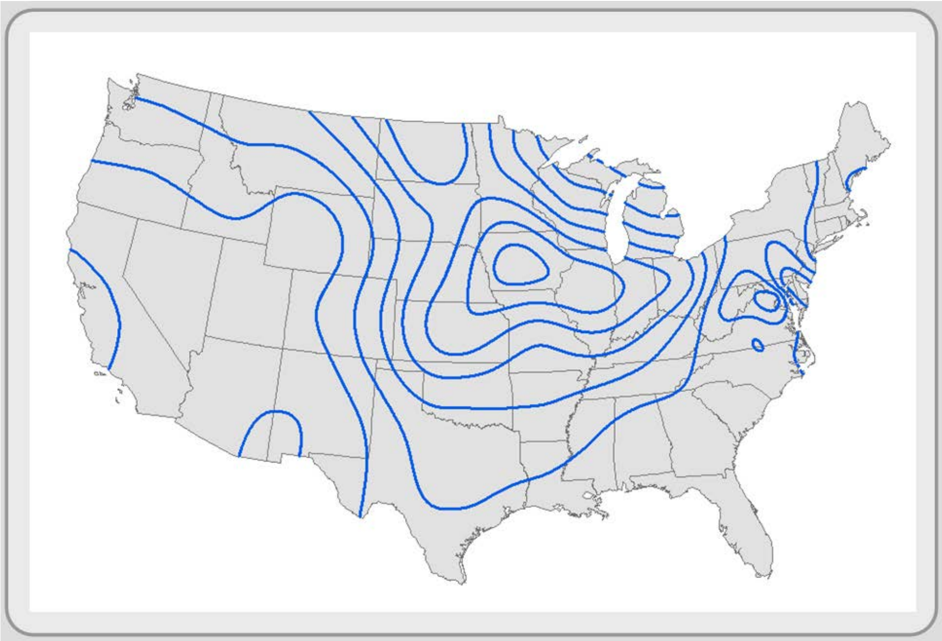

Figure 6.4: Isoline map.

***Graduated Symbol Map***

Graduated symbol maps use symbols that occur at points across a map, but unlike dot maps, the symbol size varies based on quantity or magnitude (see Figure 6.5). Usually one graduated symbol is generated from within each polygon feature, and its symbol size is determined by the polygon's attribute value. Higher values get larger symbols. Graduated symbol maps depict ordinal or interval data. The symbols can be circles, squares, or just about any form. Point feature layers can also be used to create graduated symbol maps.

There are two kinds of graduated symbol maps (both are vector based): Proportional symbol maps have symbols that are equivalent to the quantity represented. Range graded symbol maps use a user-defined number of classes each with a different-sized graduated symbol to represent its magnitude. Each symbol represents a range of values, not a single value.

*Data type:* Ordinal and Interval

*Feature type:* Polygon and point

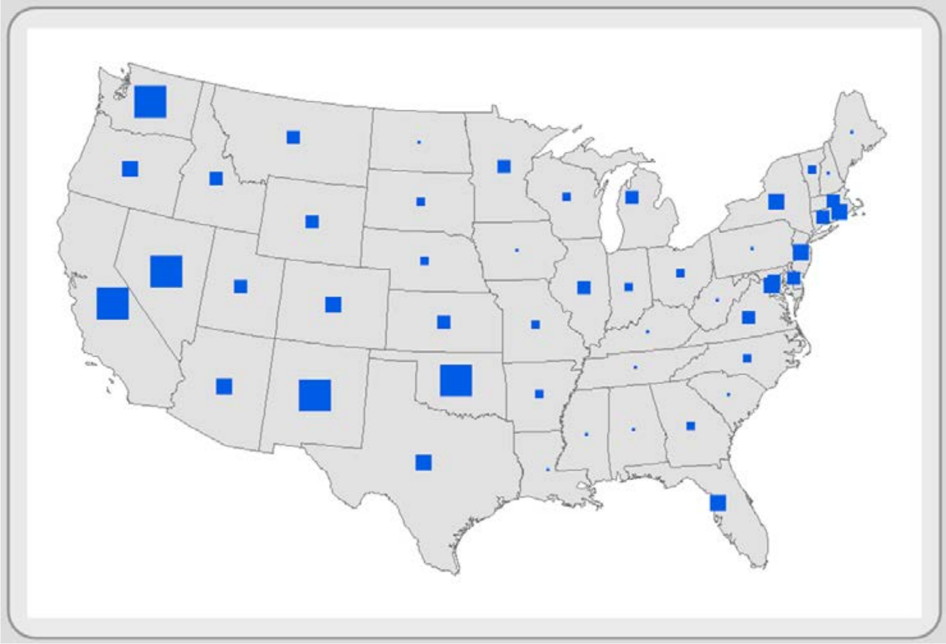

Figure 6.5:  Graduated symbol map.

***Choropleth Map***

Choropleth maps are the most common and easily recognized of the thematic maps (see Figure 6.6). They show ratios, proportions, and percentages that are aggregated within polygon features.  They use grays and colors to depict each polygon's (or each pixel's) attribute value.  An election map, depicting shaded states of blue or red—based on the percentage of votes cast for a politician or a party—is an example.  Like graduated symbol maps, choropleth maps have proportional and range graded variations, but true choropeths only use ratio data.  Simpler "shade" or "color" maps use nominal or ordinal data.

*Data type:*  Rate, proportion, or percentage

*Feature type:* Raster or Polygon

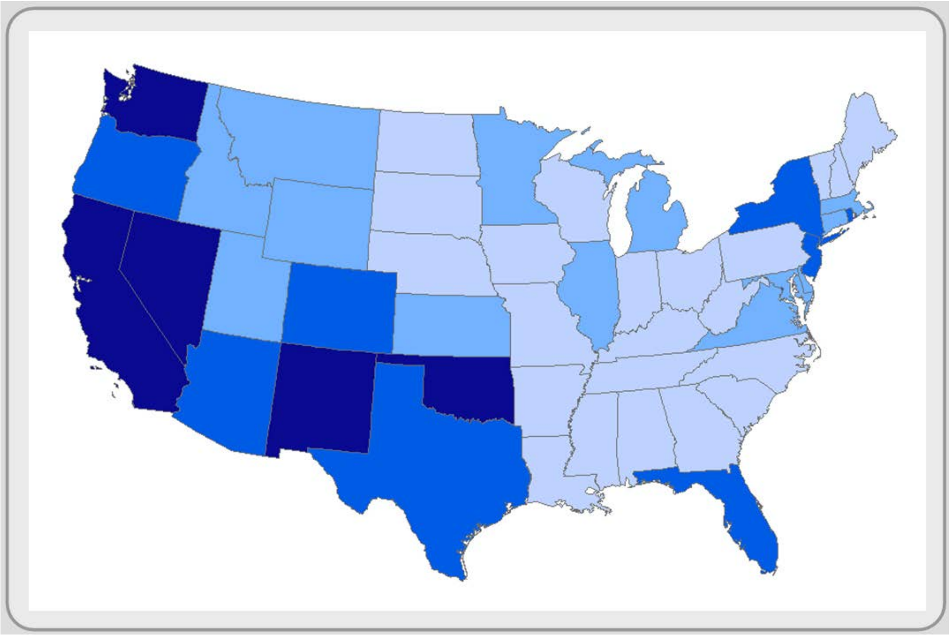

Figure 6.6:  Choropleth map.

### *Cartogram*

Cartograms distort polygon shape to depict the magnitude of attribute data (see Figure 6.7).  A high value within a normally small geographic unit (polygon) creates a large geographic unit on the map because the size of the polygon is based on the feature's attribute value.  There are different types of cartograms; they vary on the degree to which the geography is preserved.   Broadly, there are two types of cartograms: Non-continuous is the simplest and easiest to construct.  The polygons do not need to touch each other. They grow and shrink, but they maintain their shape.  Contiguous cartograms maintain their connections with each other, but to do this, they distort the shape of their polygons.  Cartograms are vector-based, but most commercial software packages do not have a routine to create cartograms.

*Data type:*  Interval and Ratio

*Feature type:* Polygon

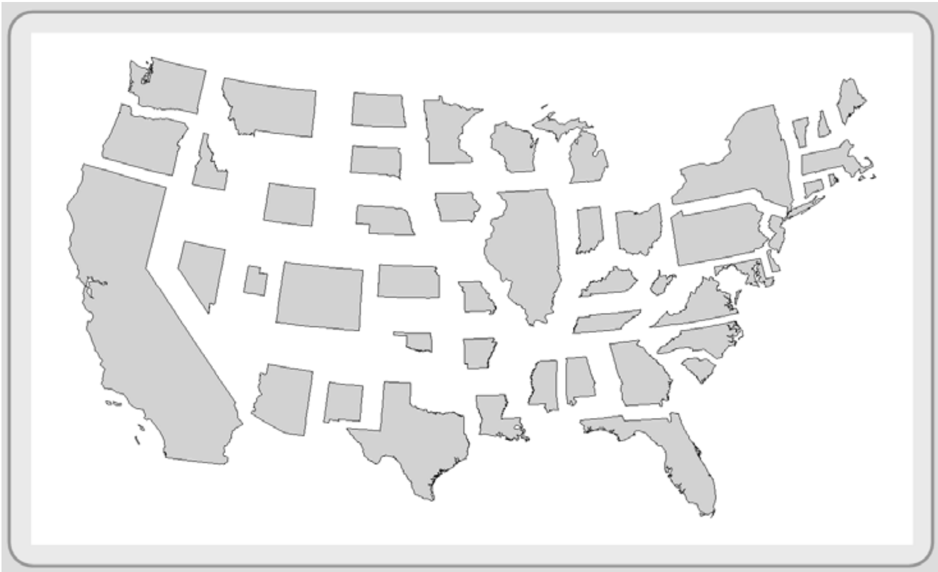

Figure 6.7:  Cartogram.

### ***Flow Map***

Flow maps show the movement of goods, people, and ideas between places (see Figure 6.8).  Usually they depict interval data by differentiating the width of the lines connecting places.  Simpler types of flow maps could depict nominal and ordinal data.  Flow maps are vector-based, but most commercial software packages do not have sophisticated flow-mapping routines.

*Data type:*  Interval

*Feature type:* Line

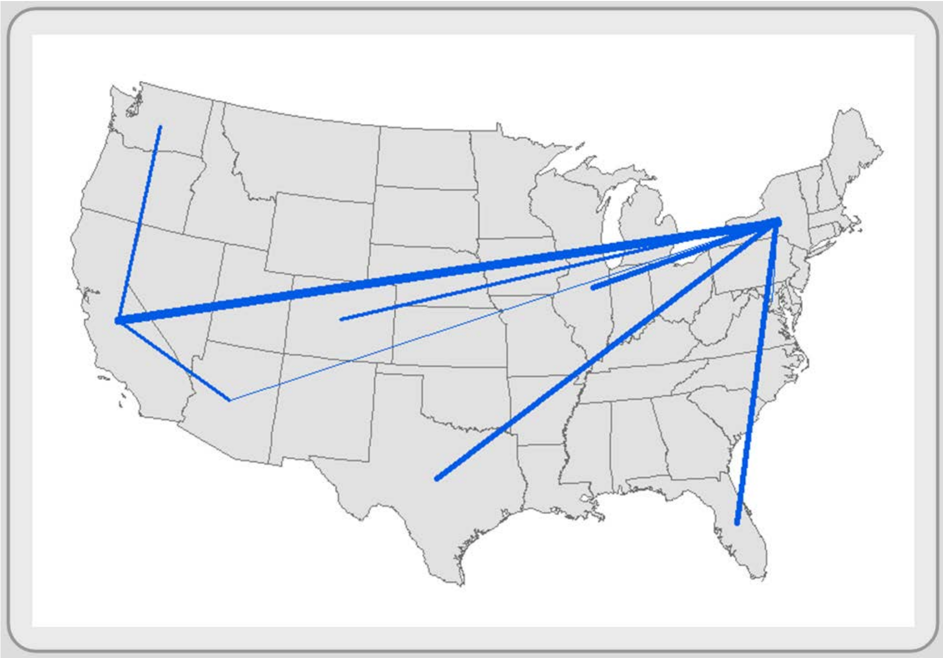

Figure 6.8:  Flow map.

### ***Density Map***

Density maps depict the concentration of points (and less often lines) across a continuous surface (see Figure 6.9).  Conceptually, each point in the feature layer spreads out its presence beyond its immediate location to include adjacent areas.  Then, each cell in the raster output image makes a circular search around itself to determine how many points (or lines) fall within the circular radius.  These maps most often depict feature counts, but density can also be derived from one of the point layer's attribute fields.

*Data type:*  Interval

*Feature type:* Point

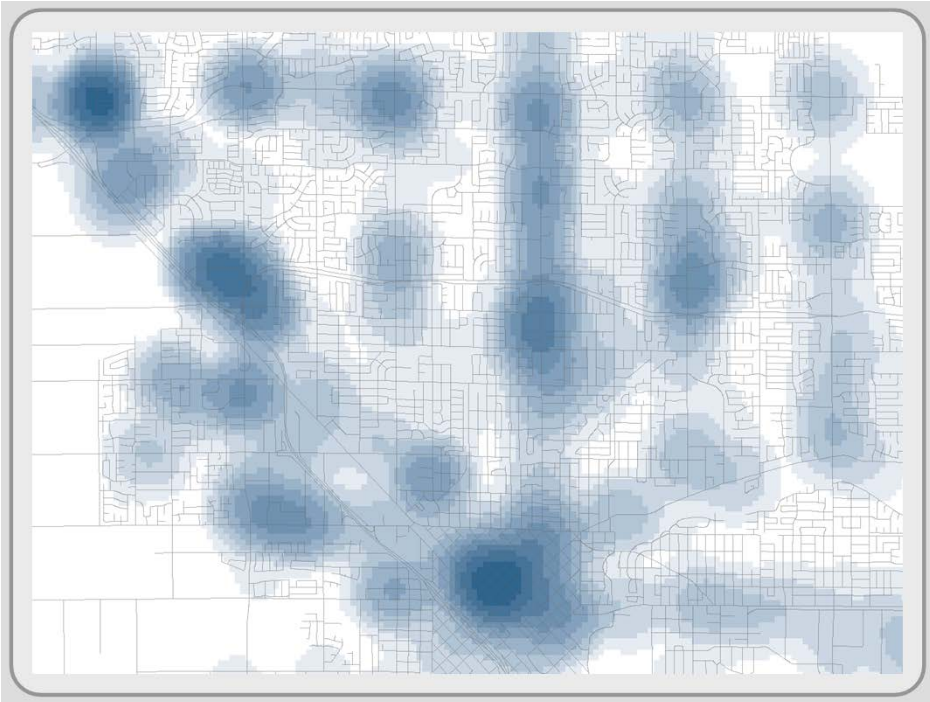

Figure 6.9:  Density map.

## CONSTRUCTING THEMATIC MAPS

Successful maps are understood by their audience.  GIS programs provide quick and powerful ways to produce maps, but good maps are not always the result.  Your task is to create maps that communicate well.  The following are 14 rules you should consider when producing maps.

***1. Pick an Appropriate Mapping Technique.***

The maps described above indicate the necessary feature and data types needed to create them. You may need to change your feature type (points, lines, polygons, or raster surfaces) or your data type (nominal, ordinal, interval, ratio, rate, proportion, or percentage) to use a desired mapping technique, or you can use the proper map technique for the data and feature type you already have.

While choropleth maps are the most common thematic map, they are also the most misused.  Instead of using rate, proportion, or percentage data, they often exhibit count data (interval and ratio data), which produces faulty impressions about the data's distribution across a map. The problem is that smaller geographic units may have lower counts and larger units may have higher values. In addition, the dark gray tint that a large state exhibits captures the eye more than the same shade on a small state. If you need to use count data, use graduated symbol maps.

***2. Show the data.***

Edward Tufte, in his book, *The Visual Display of Quantitative Information* (1983), states: "Above all else, show the data." Although he was primarily writing about graphic design, it is also the most important rule concerning map design. Maps must draw the reader's attention to their substance—their theme—not to something else. To "show the data", you should maximize the size of the map frame (which includes the base map and theme). Make it as large as possible. Then, focus the map's ink on the theme. In the advertisement in Figure 6.10, the "data"—the watch—is maximized.

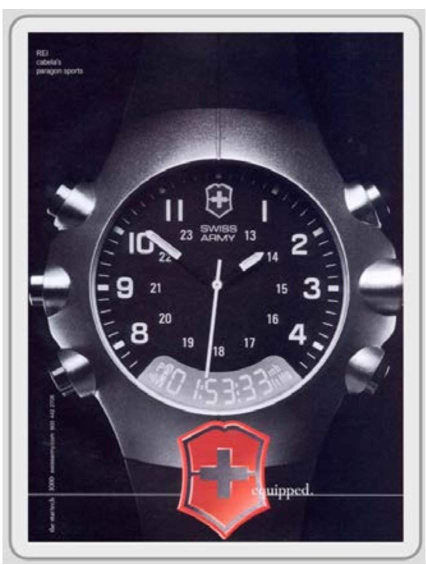


Figure 6.10: Show the data.

After the map frame, the most important elements are the title and then the legend. These elements need to occupy prominent positions. When given a map to read, your eyes should snap to the map frame (and its theme), title, and legend (in that order). As a first approximation, the most important elements should be located near the top or just inside the left-hand margin of the page.  Less important and ancillary map elements can be positioned along the bottom and toward the right (see right-hand map in Figure 6.11).

***3. Map balance.***

Once the elements are arranged to reflect their importance, give attention to the map's overall balance (see Figure 6.11).  Distribute the map elements as evenly as possible within the map's border to avoid unnecessary crowding or, conversely, large blank areas, called white space.  When balancing a map, consider its color, shape, and the size of both the map frame and the other map elements.

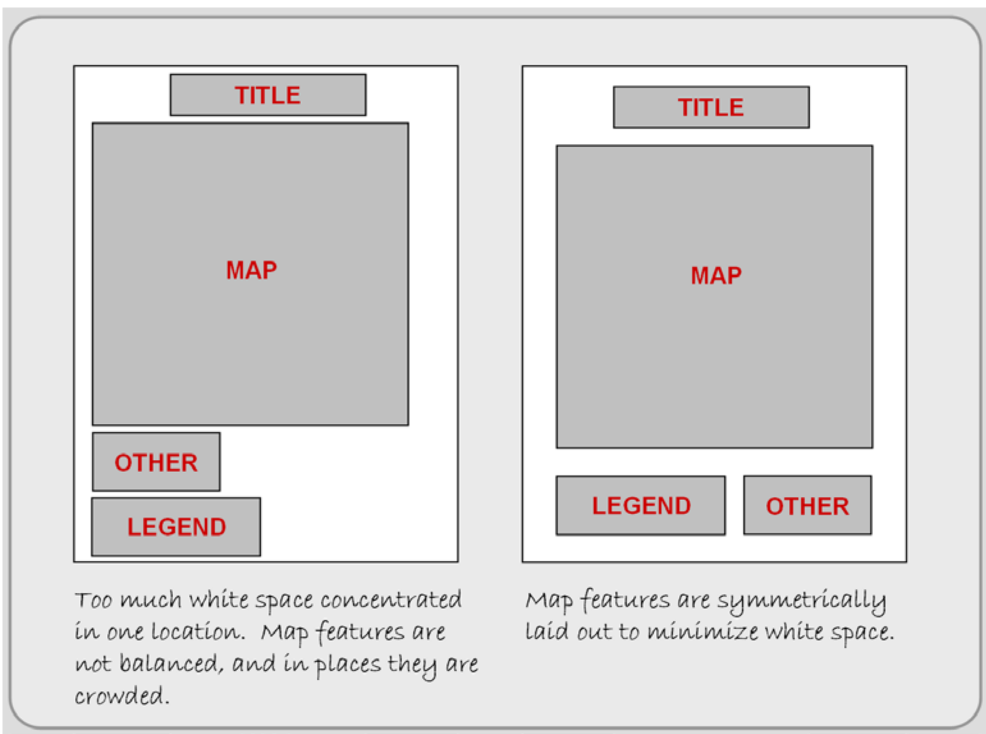


Figure 6.11:  Map balance.   The map on the right displays little white space with its symmetrical layout.  Asymmetrical layouts also work as long as they minimize white space and present the map features in a logical interpretive order.

***4. Visual Contrast***

Contrasts should be striking.  It is important to establish a visual hierarchy both for the map features that depict the data—the darker and larger features will stand out (see Figures 6.5 and 6.6 as examples—and for the text (larger fonts should be used for the most important text). Good visual contrast shows the map reader what is most important. It catches their eye. Other features should fall into the background. Psychologists say that dark areas, heavy patterns, complex shapes, and recognizable figures stand out, so make sure on your map that you want them to.

***5. Clarity and Legibility***

Your map needs to be both clear and legible. For clarity, do not overload the map with too much information and place the map elements in logical positions. Ask yourself, does the map make sense? Is it clear? Is it laid out well?

For legibility, make your lines sharp and the grayscale shades in a choropleth map distinguishable from each other. When it is important to make distinctions, show the differences in your features by using different sizes (dot size, width of lines, font size), textures (solid lines versus dashed or dotted lines), and colors. For example, large cities might be identified with a big black square and highlighted with a larger font than smaller cities and towns. Freeways and major highways might be highlighted by a thicker and darker line than less used roads.

***6. For choropleth and graduated-symbol maps, pick an appropriate classification method.***

To create a graduated symbol or choropleth map, you need to answer two questions: 1) Which classification method displays your data most accurately? 2) How many classification categories (or classes) will you have? The first question addresses an important point: you need to depict as accurately as possible the underlying distribution of the field's attribute values. We call this simply the "data's shape." This is a somewhat difficult—but important—task because the whole point of displaying the attribute values cartographically is to generalize the data to present or reveal its spatial pattern. Using the wrong classification scheme distorts the data and obscures spatial patterns. There are many classification methods including equal interval, quantiles, arithmetic progression, standard deviation, and natural breaks (these are discussed below).

The answer to the second question may come more naturally. If you have too few categories, the map may obscure the data's distribution. Too many categories are just as fruitless and equally unlikely to reveal spatial patterns. In addition, it is difficult for most map readers to distinguish among more than seven classes. Except for some maps that display nominal data, seven or more classes are too many and the map becomes an illustrated table. Try to use between three and six classes. Let the data's shape help you decide. Create a histogram of the attribute field you want to map (see Calculating Descriptive Statistics in Chapter 5). Frequently, you might discover natural valleys (called cut points) that could define individual classes. It takes some training, but it will become easier. In other cases, the data's shape might give you very little feedback, and you will have more command over the number of classes your map uses.

Regarding classification methods, Figures 6.13 to 6.17 portray the median age of California's 58 counties. Even though they use the same attribute and have five classes apiece, they look somewhat different because each map uses a different classification method. The first map uses equal intervals (Figure 6.13), the second is divided into quantiles (Figure 6.14), the third is arithmetic progression (Figure 6.15), the fourth uses standard deviation (Figure 6.16), and finally, the last map has user-assisted natural breaks (Figure 6.17).

Even though the maps use the same attribute field, they convey different spatial patterns. Other attribute fields might reveal greater variation among the maps. The five maps in this example are a bit subtle, but variation still exists. The equal interval method seems to stress the lowest population values while the arithmetic progression method accentuates the highest categories. You use different ranging methods to generalize different types of data distributions. Each classification method is suited to a particular data "shape".

Therefore, the first step in preparing a choropleth or a graduated-symbol map is to explore the shape of any statistical dataset you plan to map (left hand graphic in Figures 6.13 to 6.17 are examples). To do this, you should plot a histogram (or a dot plot) of the data and employ basic descriptive statistics to explore the data’s shape and distribution. As stated above, many GIS programs provide options that graph data and automatically calculate descriptive statistics like mean, mode, median, range, and standard deviation (see Chapter 5). Figure 6.12 depicts various generalized dataset shapes.

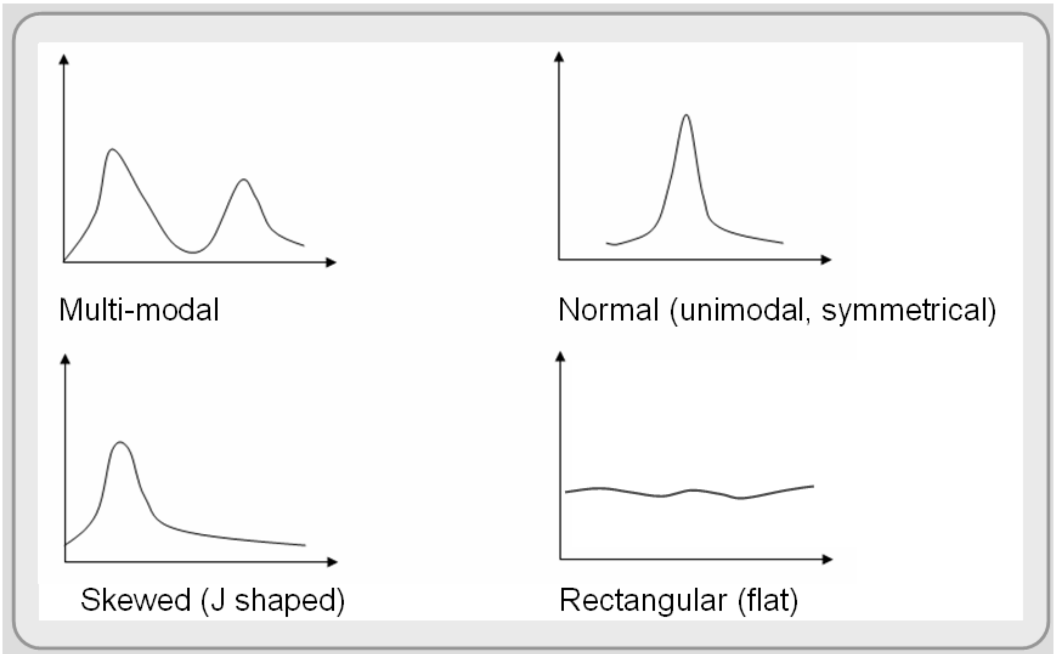


Figure 6.12: Generalized data shapes. The shape determines the classification method you use.

In generalizing statistical distributions, cartographers use the term "cutpoint" to refer to the boundaries between categories. The following classification methods differ in how they assign cutpoints. Some of the most commonly employed ranging methods include:

A. Equal Interval (also called Equal Steps or Equal Size) - This method takes the difference between the low and high values of a distribution and divides the difference into evenly spaced intervals. If 0 and 10 were the low and high values of a distribution, and you wanted to divide the data into five categories, the cut-points would be: 0, 2, 4, 6, 8, and 10. Each category will be differentiated by its own shade or pattern. The method is useful for mapping rectangular (even) distributions.

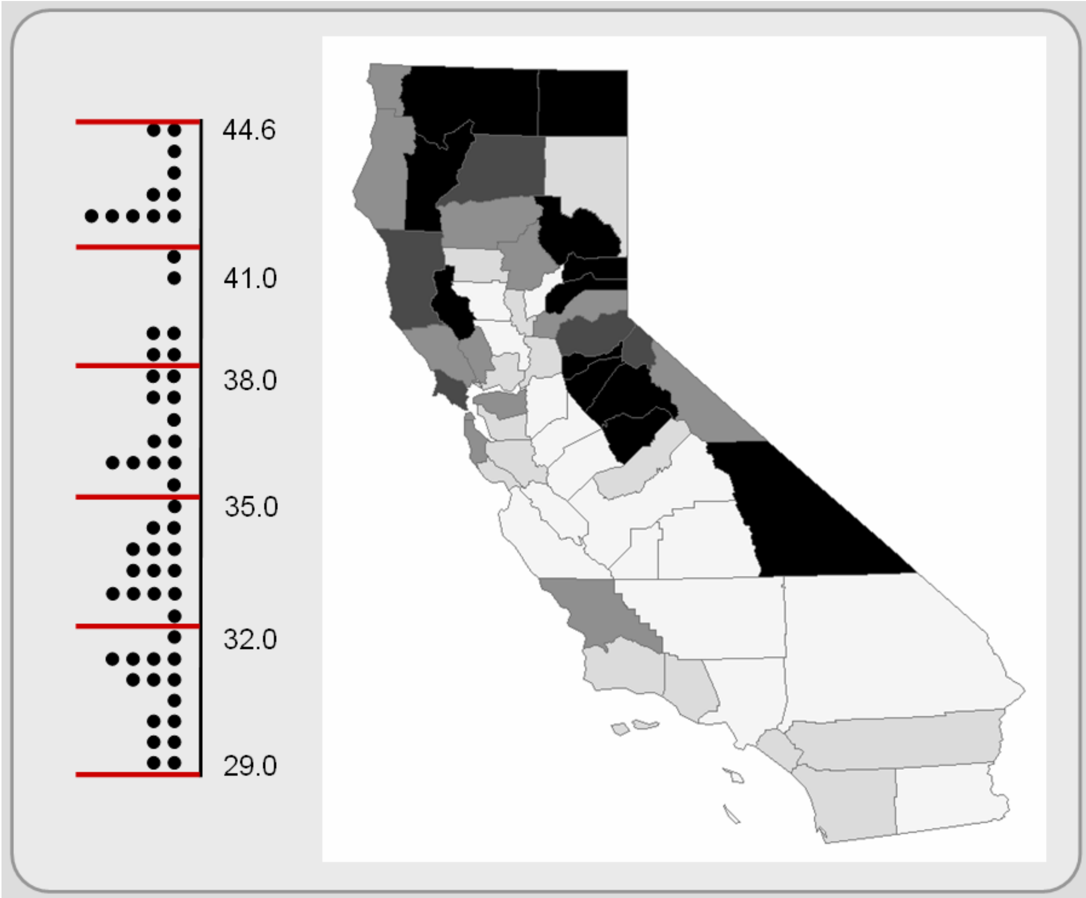


Figure 6.13:  Equal interval classification method.

B.  Quantiles (and Percentiles) - This method arranges your attribute values from low to high and places equal numbers of observations in each category.  If your data included one hundred observations and you wished to divide the data into five categories, the lowest twenty observations would be placed into category one, the next twenty into the second, and so on until the highest twenty observations were placed into category five.  The percentile method is similar to the quantile method described above; it, however, places equal percentages of the observations in each of the categories.  Both of these methods are also useful for mapping rectangular distributions.

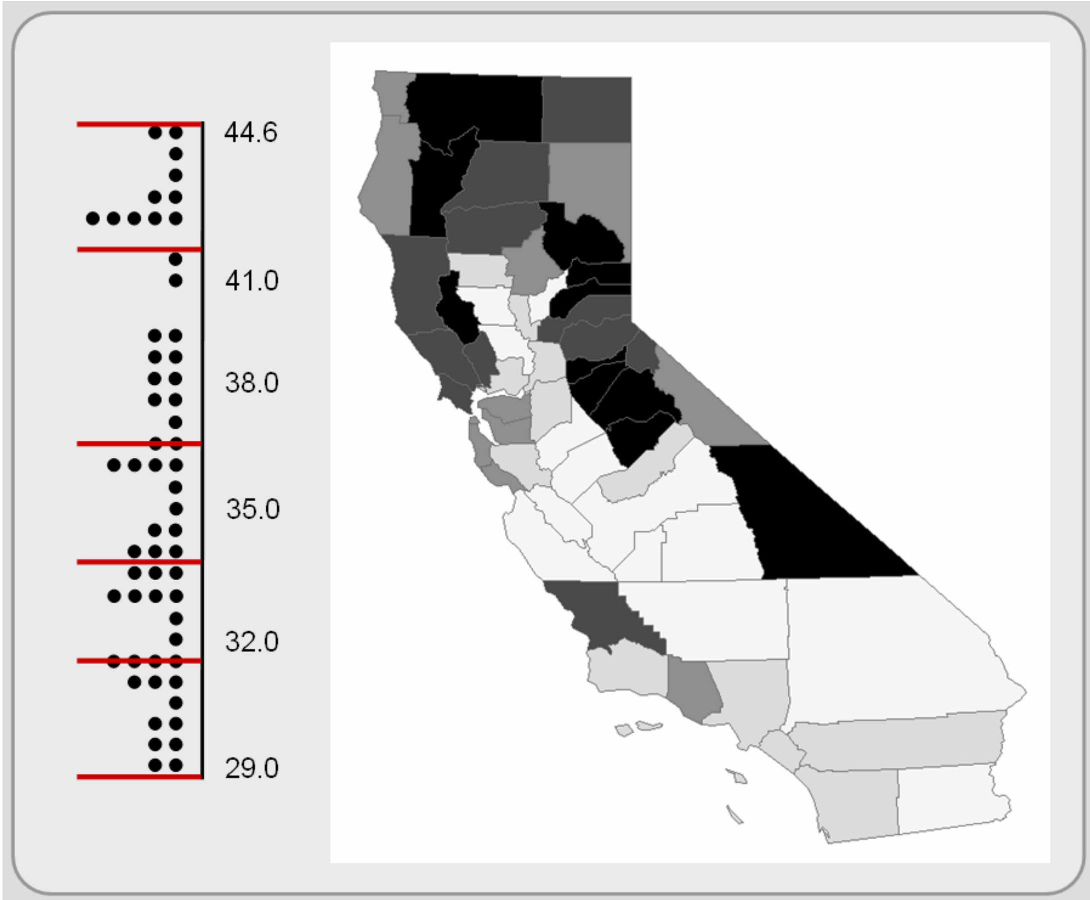


Figure 6.14:  Quantiles (Quintiles) classification method.

C.  Arithmetic Progression - In this method, the widths of the category intervals are increased in size at an arithmetic (that is, at an additive, multiplied, etc.) rate.  If your first category is one unit wide and you choose to increment the width one unit at a time, the second category would be two units wide, the third three units wide, and so forth to the end of the distribution. This method can be applied to J-shaped or heavily skewed (either positive or negatively skewed) data.

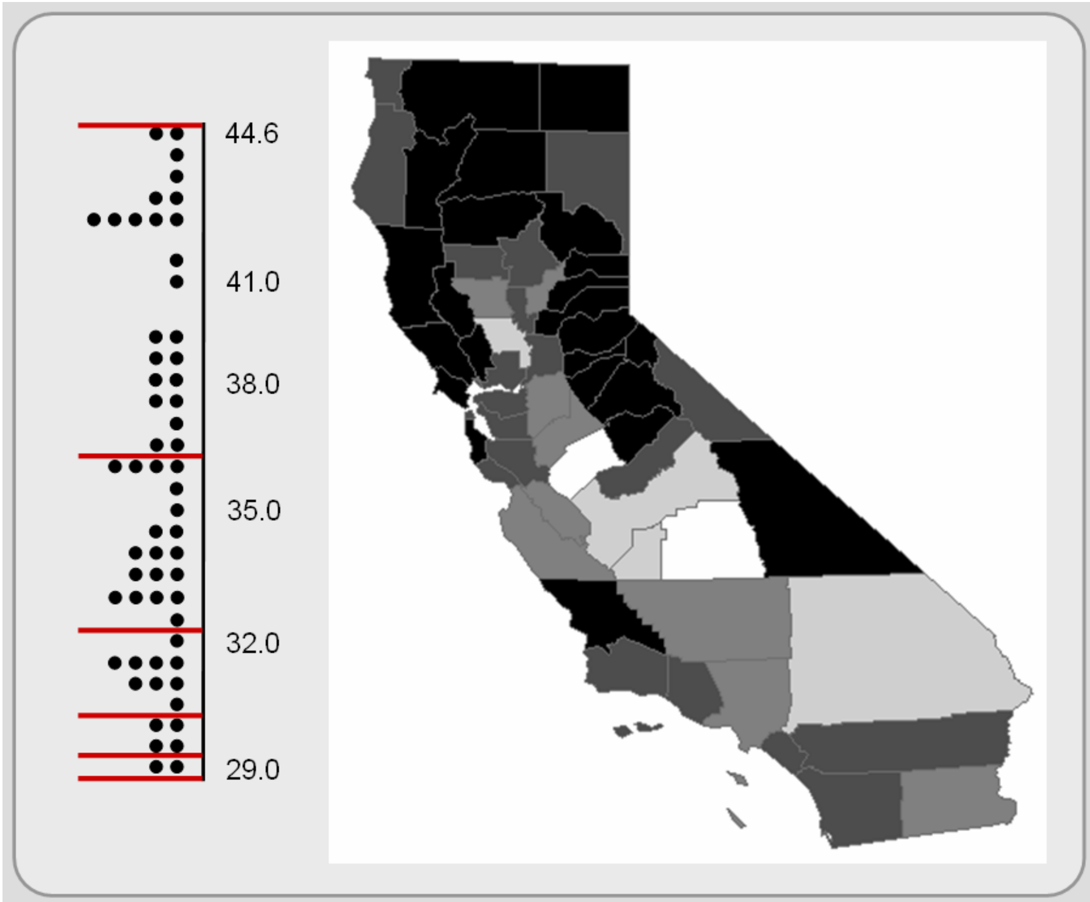


Figure 6.15:  Arithmetic Progression classification method.

D.  Standard Deviation - In this method, the standard deviation of the distribution is used to set the cutpoints above and below the mean.  This method should only be applied to distributions that approximate a normal or bell-shaped distribution.

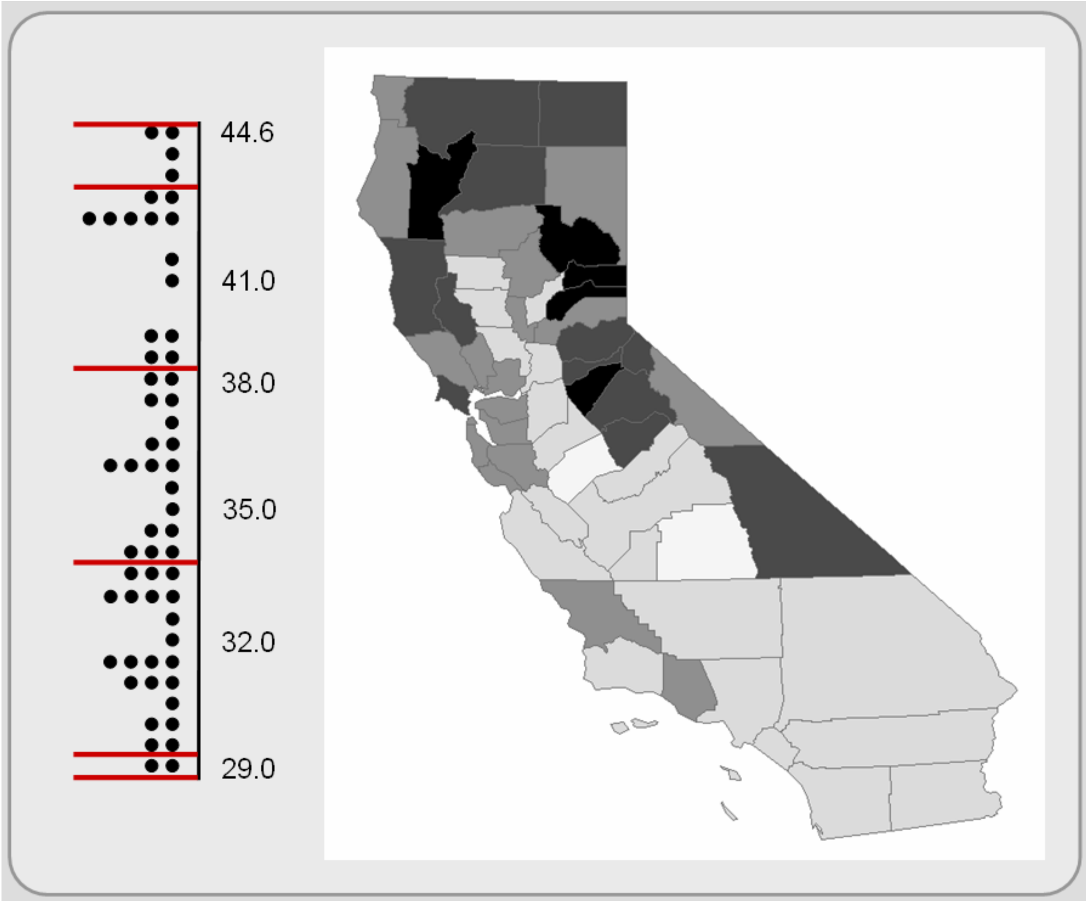


Figure 6.16:  Standard deviation classification method.

E.  Natural Breaks (Discontinuous) - This classification method creates classes by grouping clusters of similar values.  If your data has several peaks, the valleys in between are the breaks (or cutpoints).  You can manually adjust your cut points when visually inspecting the data's distribution.  This is a good choice for data sets that are multi-modal or those that do not approximate some of the before mentioned data curves.

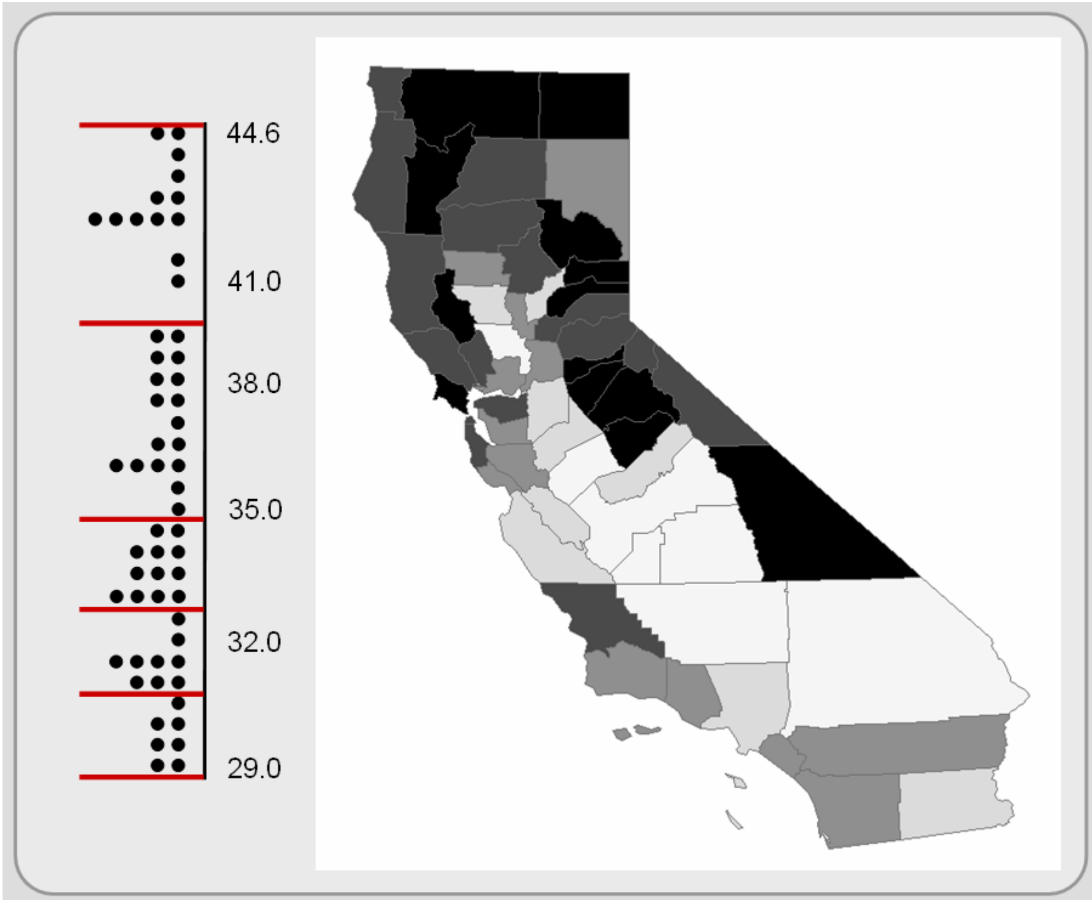


Figure 6.17:  Natural Breaks classification method.

### 7. *General Considerations about Text.*

The lettering that goes on a map is important.  Plan your text just as you plan the rest of your map.  All text should be map-reader friendly, so spell out words, run words from left to right, avoid running words vertically, and do not use words that are mysterious and grandiose.  An exception to this is the use of U.S., which at least to a U.S. audience is understandable.

Also, include little messages on the map that help explain some of the patterns.  Ask people to read and interpret your map's text.  If anyone is confused, rewording is necessary.

Typography is the appearance of type.  Type should be clear, precise, and modest.  Like your map, it should be legible and clear.

There are four major type elements: style, form, size, and contrast.  The type's style refers to fonts and the presence or absence of serifs.  Fonts are the shape and pattern of letters.  There are thousands of fonts, and a short list includes Helvetica, Arial, Universal, Times, and Courier.  Generally try to limit your map to one font.  Two can work well, but you should have a good reason for additional fonts.  Do not pick a font that is too ornate.  It catches the map reader's eye, when you want the map's theme (the data) to catch the eye first.

Serifs are the attachments found at the end of some letters.  Sans-Serif means that the font is without serifs.  Studies indicate that Sans-Serif fonts can be read more rapidly, but less information is retained.  Serifs provide greater comprehension, possibly because there is greater differentiation among letters that have serifs.  As a guideline, use serifs, but nothing too ornate, for your larger text.  Most Sans-serif fonts, however, are a better choice for smaller text because it is easier to read.


Figure 6.18:  Serif and Sans-serif fonts.

The form of type includes case (upper, lower, mixed), italics, and boldfacing.  Capitalization indicates something is important, but capitalized text is harder to read, so try using mostly mixed case.  Book titles, water bodies, and referenced titles should be italicized (not underlined).  Underlining will catch the map reader’s eye too much.

The size of type has been traditionally measured in points.  1 point is 1/72 of an inch.  Increasingly, some systems use conventional units like inches or millimeters to measure size.

The contrast of the type with the background is important for legibility.  Your type should always stand out from the background unless you want a small message on your map to be recessed.  Shadings frequently fades-out lettering, so you can remove the shading underneath the type if it is too difficult to see.

On maps, text is used for titles, legends, explanations, source statements, labels, scales, and other map features.  Specifics regarding text for these map elements are discussed in the following sections.

***8. Titles and Subtitles.***

Titles must relate to the map's topic clearly.  Good titles require thought, and the following should be considered when constructing a title:  make it clear, keep it brief, and start the title off with the subject of the map (the noun) if you can.  Never start the title with "Map of…"

Subtitles are frequently used in a series of maps to denote changing locations, time, or conditions. Subtitles should be reserved for detailed data and should always be smaller in size than the title.

***9. Legends.***

Legends contain explanatory text and list the symbols used on a map.  The symbols in the legend should appear exactly as they are on the map.  Not all maps require legends; sometimes the necessary information is found in a caption or in the text of an article.

When annotating your legend, be clear and concise; try not to repeat the words you have in your title and subtitle.  The legend text should explain the legend's symbols, but it should not use the word "Legend" or "Key".  It should be obvious.

***10. Scale.***

You must provide a scale unless the audience is intimately familiar with the geographic area or distance is of no importance.  Scales should not contain the word "Scale".  There are verbal, numeric (1:24,000), and graphic scales, but graphic scales are preferred because they maintain their relative size when maps are shrunken or enlarged.

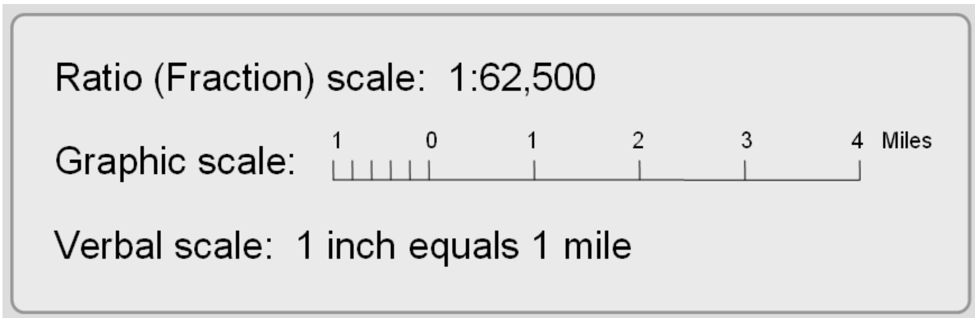


Figure 6.19:  Different types of scales.

***11. Source Statements.***

Most thematic maps need a statement about the data's source and date.  If you are using copyrighted material, you must get permission, and the publisher may specify the wording of the statement. Additional text you might provide includes the name of the map's cartographer and the map's projection (coordinate system).  Most of this information should be located at the bottom of the map (perhaps near the right-hand boarder) and the text should be small (usually the smallest on your map).

***12. Labeling.***

Labeling gives descriptions to various features and provides the flexibility to attach descriptions to individual point, line and polygon features.  The Swiss cartographer Eduard Imhof (1975) provides six basic rules for label placement.  Labels should:

- be legible.
- have clear association with the features they describe
- not disturb other map contents
- assist to show the feature’s extent
- reflect the classification and hierarchy of features

- not be evenly dispersed nor clustered together

Additional rules might include:

- place the names on the land or at sea
- not be curved unless necessary (unless following a river's course)
- take precedence over line work
- be connected with the feature by the use of an arrow if the label cannot be placed near the feature.

Their positioning can be difficult and frustrating at times. It may not be possible to satisfy all of these labeling rules. As Imhof emphasizes: "no rule without exception" (1975, 29). Two rules often stand in opposition. You must consider each conflict individually, and choose the best solution.

### *13. North Arrows*

Unless it is obvious, provide a north arrow, but keep it small and simple.

### *14. Use of color.*

Color can dramatically heighten your message, or it can be a distraction for the map reader. There are so many pitfalls, that Edward Tufte warns us about the use of color: "Above all", he says, "do no harm" (1990, 81).

Color can be used throughout your map, but the most important color decisions involve your map features and especially the theme portrayed. For your theme, color choices depend on whether it's based on qualitative or quantitative data (see Chapter 2). Qualitative data are best mapped using unalike colors (or different patterns if the map is black and white), each having the same weight or brightness. A sequencial color scheme, using a single hue, ranging from light to dark, should not be used. This type of color scheme insinuates that one color (and thus, one category) is greater than the other.

If the theme uses quantitative data, you must decide if the data is uni-polar or bi-polar.  Most data are uni-polar, which means there is no natural or meaningful dividing point.  A parcel's acreage and price are examples.  For uni-polar data, a sequential color scheme is recommended.  Imagine a pallete starting with a very light blue and graduating through medium blues to conclude with a dark blue.  The eye tends to be led by these patterns of light and dark, and dark (Tufte's ink) catches our eye first. For this reason (as well as tradition), darker shades should mean "more".

Bi-polar data, on the other hand, has a dividing point that makes sense.  The natural increase rates of countries are an example.  Most countries have more births than deaths, so they have positive growth rates.  Several countries, however, possess negative natural increase rates.  In this case, zero is a clear divide in the attribute values.  An attribute's mean and medium can also be used to divide data (but it must make sense).  For bi-polar data, diverging color schemes—those that have two distinct hues—are recommended.  An example might start dark green, progressively get lighter until it becomes gray-like, emerge as light red, and progresively get darker red.

In all cases, the color of each class must be clearly distinguishable from each other.  Sometimes the category colors may appear to be discrete on the computer screen, but if the purpose is a printed map, you must test the colors with a hard-copy print (because they will vary).  Also note that colors vary on different printers (even different makes from the same manufacturer) so beware.  If you use a data projector to display your map, understand that some colors (especially yellow) get washed out and may be hard to see against a screen.  Also, color features against a light gray or muted color background stand out more.  It can also reduce eye strain in the map reader.

Much theory has been developed that aids cartographers in choosing colors.  As discussed earlier, different colors have emotional and cultural associations.  In addition, many colors are not perceived equally by all people, and some of these colors should be avoided.  The geographer Cindy Brewer has developed ColorBrewer (http://colorbrewer2.org/) to help you can chose different color schemes, and see how they change your perception of your results.

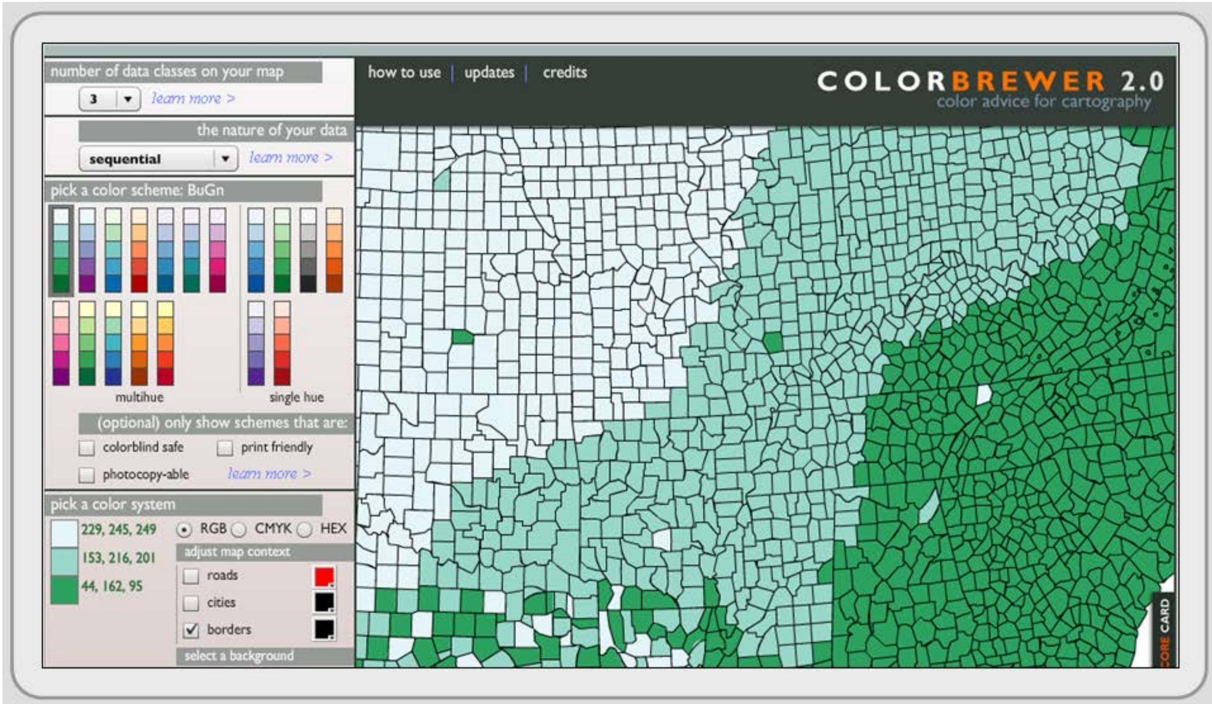


Figure 6.20:  ColorBrewer 2.0 (http://colorbrewer2.org/).

***Types of Output***

Although there are statistics, graphs, and reports, the map is the main way to depict output from a GIS. They are easily displayed, printed, modified, and re-displayed.  Maps are taking new forms, which is bending our conception of what maps are.  While printed, projected (over a data projector or computer screen), and web-based static (pdfs, jpegs, etc.) maps dominate, animated and interactive maps have appeared and are changing GIS and cartography.  Think of rotating themes on an interactive map, and looking at spatial relationships from different angles.  Multimedia technology even makes it possible to integrate sound and video, and it encourages different ways to facilitate map presentation and spatial analysis.