CHAPTER

4

MAP DESIGN

OBJECTIVES

Chapter 4 briefly describes the common features of maps used in natural resource management. The emphasis of this discussion is on developing maps to be used by field professionals in presenting results of GIS analyses or in creating maps for harvest plans, wildlife surveys, and so on. At the end of the chapter, some of the features that one would find on the highly professional maps of the U.S. Geological Survey (e.g., 7.5 Minute Series Quadrangle maps) are described. At the conclusion of this chapter, students should have acquired a firm understanding of the following map development concepts:

1. The main components of a map
2. The qualities of a map that are important in communicating ideas
3. The types of maps that can be developed to communicate ideas to others

Maps are amazing tools, which, if constructed correctly, have the ability to communicate information quickly and clearly to an audience. Within natural resource management, one might come to expect that maps will be available for resources and areas one manages. Maps are an effective method of illustrating ideas and representing spatial relationships among landscape features, and they are engaging—people are usually drawn to maps describing certain phenomena. Most GIS software programs allow GIS users to produce sophisticated maps; thus, people tend to associate GIS with mapping activities. Although this association may tend to ignore the other analytical capabilities of GIS, the ability to portray geographically the results of an analysis is one of the distinguishing characteristics that sets GIS apart from other software programs.

Maps have been part of human civilization for millennia and have been used for a variety of purposes, including data storage, navigation, and visualization. Like statistics, maps can hold tremendous power over the message that is delivered to an audience and, when created skillfully, can be used to influence people’s opinions (Monmonier 1995, 1996). One of the great dangers presented by maps is the assumption that the landscape features and representations on maps are accurate portrayals of the natural resources they claim to represent. At best, maps are abstractions of the real world and usually possess some measure of nonconformity—directional, proportional, or both—from the
landscape features they attempt to present. Understanding that maps must be created and interpreted with a discerning eye is one of the first steps necessary to becoming a successful mapmaker or map user.

Maps usually are two-dimensional representations of landscape features (although three-dimensional maps can be used to show volume or perspective), that use symbols, colors, and text to represent spatial phenomena. Cartography is the art and science of making maps, and, although this book was not intended as a book on cartography, many of the applications at the end of this chapter emphasize the development and use of maps to help describe the landscape. Maps are graphic representations of information, as are graphs, flowcharts, and other diagrams. Maps attempt to get across ideas to users in a different manner than other types of graphic representations, with the hope that the human brain, with its limited capacity to store information, will have an added ability to understand those ideas (Phillips 1999). The design of a map can affect the ability to communicate spatial information; thus, a well-designed map will likely communicate ideas to coworkers and supervisors more effectively than a poorly designed map. Poorly designed maps can lead to misinterpretations by the intended users, facilitating costly or inappropriate decisions.

Maps should be clear enough to enable users to understand (1) the land area the map represents and order to do so, a variety of common tools are used, to help them navigate through a landscape. Two important aspects of maps that map developers should keep in mind are (1) not everything that is known about a landscape needs to be displayed on a single map and (2) to communicate effectively, maps should focus on showing a limited number of landscape features. The landscape features primarily emphasized on a map should be those associated with the intent of the map. On a map developed to illustrate stream classes, for example, other landscape features, such as roads, timber stands, and soils, should be secondarily emphasized or omitted from the map entirely.

**Map Components**

There are several basic components that are important to include in a map: the symbols being used to describe landscape features, a north arrow, the scale, the legend, topographic symbols, and soils, should be secondarily emphasized or omitted from the map entirely.

**Symbols**

A variety of map symbols have been developed to identify significant landscape features. Some symbols represent national standards for identifying landscape features, such as those found on U.S. Geological Survey topographic maps (e.g., contour lines, hydrologic symbols (figure 4.1)). Other symbols represent organizational standards for identifying landscape features. For example, the U.S. National Park Service has created a standard set of symbols for use on National Park Service maps (National Park Service 2001). On a smaller scale, the University of Nebraska–Lincoln (2001) has developed standard symbols for use in its transportation maps, and the U.S. Orienteering Federation (2001) has developed a set of standard map symbols for orienteering events.

Most GIS software programs also provide a set of standard map symbols for map users; however, map developers can easily misuse the symbols, since documentation is usually limited within the dialog boxes provided by the software. Nevertheless, a variety of symbols are available in GIS software programs to describe landscape features. It is also possible within many GIS software programs to create a customized symbol set. In some GIS software programs, symbols are merely bitmap graphic files, which can be edited or created through graphic software programs. Other GIS software programs allow the use of customized tools or products developed by third-party software developers, many of which are designed to help GIS users quickly and easily create symbols that are specific to the GIS software program being used.

**North Arrow**

Ordinal directions (north, south, east, west) are typically used by map developers to indicate map direction. It is common for maps to use a north arrow to indicate the orientation of the landscape being portrayed. Although most maps are usually oriented with north at the top of the page and south at the bottom, it is appropriate to remove the uncertainty associated with an interpretation of a map by explicitly indicating the direction through the use of a north arrow. A variety of north arrows are available in most GIS software programs, and a number of others can be developed using lines, arrows, and text (figure 4.2).

**Scale**

Scales indicate to map users the proportions of a map in relation to the landscape illustrated on the map—that is, map distance compared with Earth distance. Scales can be displayed in a variety of ways, graphically, verbally, or using a representative fraction (RF) scale (figure 4.3). When a representative fraction scale is used, such as 1:12,000, one should interpret the scale as 1 unit on the map representing 24,000 units on the ground (e.g., 1 map inch represents 24,000 ground inches, or 1 map centimeter represents 24,000 ground centimeters). Representative fraction and verbal scales are also interchangeable. For example, a verbal scale that reads 1 inch = 1 mile is the same as a representative fraction scale of 1/63,360 (1 inch = 1 mile = 63,360 centimeters). Representative fraction scales, on the other hand, are expressed as a ratio (e.g., 1:63,360, 1:50,000) and are more appropriate for representing small areas of the landscape. Graphic bar scales generally do not indicate the exact scale, as do representative fraction or verbal scales, of a map but, rather, associate the length of a graphical shape to ground distances. Whether graphic, verbal, or representative fraction scales are used, the appropriate metrics (English vs. metric system, feet vs. miles, meters vs. kilometers) and appropriate font sizes should be employed to prevent map users from becoming distracted from the map’s main message. Scale bars have an advantage over representative fraction and verbal scales in that they generally adjust accordingly when a map is rescaled or resized within a GIS software program.

**Legend**

The information contained in a map legend should describe all of the landscape features illustrated on the map, allowing users to interpret the map fully (figure 4.4). Of course, if one intends to add mystery to a map, the legend may omit the description of certain landscape features. Rarely, however, does one want a map to be an enigma to users. Most GIS software programs now offer tools that allow the automatic creation of legends by referencing the GIS databases that are being used. Typically, tools are also available for GIS
landscape features they attempt to present. Understanding that maps must be created and interpreted with a discerning eye is one of the first steps necessary to becoming a successful mapmaker or map user.

Maps usually are two-dimensional representations of landscape features (although three-dimensional maps can be used to show volume or perspective), that use symbols, colors, and text to represent spatial phenomena. Cartography is the art and science of making maps, and, although this book was not intended as a book on cartography, many of the applications at the end of this chapter emphasize the development and use of maps to help describe the landscape. Maps are graphic representations of information, as are graphs, flowcharts, and other diagrams. Maps attempt to get across ideas to users in a different manner than other types of graphic representations, with the hope that the human brain, with its limited capacity to store information, will have an added ability to understand those ideas (Phillips 1999). The design of a map can affect the ability to communicate spatial information; thus, a well-designed map will likely communicate ideas to coworkers and supervisors more effectively than a poorly designed map. Poorly designed maps can lead to misinterpretations by the intended users, facilitating costly or inappropriate decisions.

Maps should be clear enough to enable users to understand (1) the land area the map represents and (2) the message the map intends to communicate. In order to do so, a variety of common tools are used, such as north arrows, scale bars, legends, and neat lines. In addition, the landscape features illustrated on a map should include enough landmarks to allow map users to reference themselves to the mapped area and to help them navigate through a landscape. Two important aspects of maps that map developers should focus on are (1) to help communicate effectively, maps should show a limited number of landscape features. The landscape features primarily emphasized on a map should be those associated with the intent of the map. On a map designed to illustrate stream classes, for example, other landscape features, such as roads, timber stands, and soils, should be secondarily emphasized or omitted from the map entirely.

### MAP COMPONENTS

There are several basic components that are important to include in a map: the symbols being used to describe landscape features, a north arrow, the scale, the legend, locational insets, and the qualities (font, size, etc.) of the text (labels and annotation). In addition, there are other components, such as a description of the map developer, the filenames and file location of the GIS databases used, and map quality caveats, that some organizations may find necessary to include in a map. Each of these components is briefly discussed below.

#### Symbols

A variety of map symbols have been developed to identify significant landscape features. Some symbols represent national standards for identifying landscape features, such as those found on U.S. Geological Survey topographic maps (e.g., contour lines, hydrologic symbols) (figure 4.1). Other symbols represent organizational standards for identifying landscape features. For example, the U.S. National Park Service has created a standard set of symbols for use on National Park Service maps (National Park Service 2001). On a smaller scale, the University of Nebraska–Lincoln (2001) has developed standard symbols for use in transportation maps, and the U.S. Orientering Federation (2001) has developed a set of standard map symbols for orienteering events. Most GIS software programs also provide a set of standard map symbols for map users; however, map developers can easily misuse the symbols, since documentation is usually limited within the dialog boxes provided by the software. Nevertheless, a variety of symbols are available in GIS software programs to describe landscape features. It is also possible within many GIS software programs to create a customized symbol set. In some GIS software programs, symbols are merely bitmap graphic files, which can be edited or created through graphic software programs. Other GIS software programs allow the use of customized tools or products developed by third-party software developers, many of which are designed to help GIS users quickly and easily create symbols that are specific to the GIS software program being used.

#### North Arrow

Ordinal directions (north, south, east, west) are typically used by map developers to indicate map direction. It is common for maps to use a north arrow to indicate the orientation of the landscape being portrayed. Although most maps are usually oriented with north at the top of the page and south at the bottom, it is appropriate to remove the uncertainty associated with an interpretation of a map by explicitly indicating the direction through the use of a north arrow. A variety of north arrows are available in most GIS software programs, and a number of others can be developed using lines, arrows, and text (figure 4.2).

#### Scale

Scales indicate to map users the proportions of a map in relation to the landscape illustrated on the map—that is, map distance compared with Earth distance. Scales can be displayed in a variety of ways, graphically, verbally, or using a representative fraction (RF) scale (figure 4.3). When a representative fraction scale is used, such as 1:12,000, one should interpret the scale as 1 unit on the map representing 12,000 units on the ground (e.g., 1 map inch represents 12,000 ground inches, or 1 map centimeter represents 12,000 ground centimeters). Representative fraction and verbal scales are also interchangeable. For example, a verbal scale that reads 1 inch = 1 mile is the same as a representative fraction scale of 1:63,360 (1 inch on a map represents 63,360 inches, or 1 mile, on the ground). Graphic bar scales generally do not indicate the exact scale, as do representative fraction or verbal scales, of a map but, rather, associate the length of a graphical shape to ground distances. Whether graphic, verbal, or representative fraction scales are used, the appropriate metrics (English vs. metric system, feet vs. miles, meters vs. kilometers) and appropriate font sizes should be employed to prevent map users from becoming distracted from the map’s main message. Scale bars have an advantage over representative fraction and verbal scales in that they generally adjust accordingly when a map is rescaled or resized within a GIS software program.

### Legend

The information contained in a map legend should describe all of the landscape features illustrated on the map, allowing users to interpret the map fully (figure 4.4). Of course, if one intends to add mystery to a map, the legend may omit the description of certain landscape features. Rarely, however, does one want a map to be an enigma to users. Most GIS software programs now offer tools that allow the automatic creation of legends by referencing the GIS databases that are being used. Typically, tools are also available for GIS

---

**Figure 4.1** Common USGS topographic symbols. (Source: USDI U.S. Geological Survey 2002)

**Figure 4.2** Commonly used north arrow designs.

**Figure 4.3** Graphical, verbal, and representative scales.

**Figure 4.4** Map legend.
users to modify automatically created legends to suit their needs. Legends can take many forms and can use symbols, points, lines, polygons, colors, patterns, and text to clarify what viewers see on a map. Legends should also utilize the appropriate font and size of type without detracting from the message of a map. In addition, the appropriate descriptors should be used and abbreviations avoided if interpretation might be unclear or if a broad audience is targeted.

**Locational Insets**

It may be helpful for the audience of a map, depending on how familiar they are with the natural resource being illustrated, to see a panel that shows the location of the mapped area in the context of a larger, more recognizable landscape feature, such as a drainage basin, forest, county, or state boundary. Often, a map will indicate these areas with a locational inset (figure 4.5). The locational inset might show the location of a watershed within a drainage basin or the location of a single stand within a forest. The locational inset should be a minor component of a map and not compete with the main features for audience attention. Three other types of insets can also be used—an enlargement inset, a related area inset, and a special subject inset. An enlargement inset can be used to show more detail of a specific area located within the primary map region. A related area inset can be used on a map to illustrate features that are noncontiguous with the main map figure yet are still important to display. Related area insets, for example, are often included in maps that illustrate the 50 United States; Alaska and Hawaii are positioned in the insets, rather than in their actual geographic location, which would necessitate illustrating portions of Canada and vast expanses of the Pacific Ocean. A special subject inset can be used on a map to show different thematic representations of the main map area (e.g., precipitation, canopy cover); it is a popular mapping approach used in many atlases.

**Neatline**

Adding a neatline to a map is considered good cartographic practice, but its presence is generally less critical than that of a scale bar or a legend. A neatline is a border that surrounds all of the landscape features on a map but lies within the outside edge of the mapping medium (paper) (see figure 4.5). Neatlines can also be placed around other map elements to help keep them separate from other objects (e.g., to separate the locational inset from the legend). Usually, a neatline is composed of at least one line, but multiple lines can be used to provide a more dramatic effect. Regardless of the style, neatlines can be useful tools for bringing organization and distinction to mapped landscape features. Some GIS software programs include mapping tools that will not only create a neatline but also allow one to specify how the area contained within the neatline will be filled. For example, the background area behind the map title, landscape features, and legend can be shaded. This feature allows one to produce a presentation-quality map or poster.

**Map Annotation**

Map annotation, or text applied directly to the map, is important in further describing landscape features that might be only briefly described in a legend. In some cases, it is not practical (or possible) to indicate all the landscape features of interest through the legend, due to space limitations or the nature of the landscape features. For example, ownership boundaries may be delineated with a certain type, size, and color of line, yet the actual owners may be displayed on the maps with words, such as Georgia-Pacific or State of Alabama. Road numbers or names may be applied as labels to maps to describe the road system further. The type of markings used to delineate treatment area boundaries, such as pink flagging or orange paint, may be displayed at the appropriate places on the landscape described in a map. Surveying information, such as township and range numbers, may be illustrated on maps with annotation (figure 4.6). Finally, owners of homes near treatment areas may also be placed on a map next to the symbol that defines their property boundary, home, or other noteworthy landscape features.

**Typography**

The ability of GIS users to interpret the written information they find on maps is a function of many variables that can be described under the broad heading of typography. Some of the most important typographical elements are typeface (font), weight (bold/normal), size (point size), and case (use of capitals) of text contained on the map itself. In one study, Phillips et al. (1977) noted that the capability of people to search for and find information on a map was enhanced when the names of places were displayed in a normal weight (not bold), with letters all in lowercase, except with an initial capital. However, capitals should be used for all letters in place names when names are difficult to pronounce or need to be copied accurately. Names set entirely in lowercase have been found to be harder to locate than names set entirely in uppercase, with the initial letter slightly larger than the other letters in a name (Phillips 1979). The font chosen will undoubtedly influence the ability of users to interpret the map; thus, a normal font (such as Times Roman, Arial, or Univers) and a normal, consistent font size are appropriate for most maps.

**Source Information and Footnotes**

In some large natural resource management organizations, where data development tasks are shared by multiple people, placing the names of the people who contributed to the development of a map on the map is discouraged. However, in field offices of natural resource management organizations, where field personnel are generally responsible for developing maps to assist with on-the-ground decisions (and, hence, not specifically the development of GIS databases), it may be desirable to know who created a map and when it was created (figure 4.7). Since GIS databases may be modified frequently, knowing the date that a map was created might be as important as knowing the developer of the map. This source information allows map users to place the content of a map in perspective with the version of the GIS database(s) used to create the map. For example, suppose it is currently September...
Judith Basin and major streams

Figure 4.5 Locational inset and neatlines.

Univers) and a normal, consistent font size are appropriate for most maps.

Source Information and Footnotes
In some large natural resource management organizations, where data development tasks are shared by multiple people, placing the names of the people who contributed to the development of a map on the map is discouraged. However, in field offices of natural resource management organizations, where field personnel are generally responsible for developing maps to assist with on-the-ground decisions (and, hence, not specifically the development of GIS databases), it may be desirable to know who created a map and when it was created (figure 4.7). Since GIS databases may be modified frequently, knowing the date that a map was created might be as important as knowing the developer of the map. This source information allows map users to place the content of a map in perspective with the version of the GIS database(s) used to create the map. For example, suppose it is currently September...
PART I Introduction to Geographic Information Systems, Spatial Databases, and Map Design

Figure 4.6 Map annotation—examples of township and range lines.

Figure 4.7 Description of map developer and date of map development.

Sussex County Thinning Plan
Prepared by: Pete Bettinger
Date: 11/11/01

Description and Location of GIS Files Used
It is common for map developers to place—in a non-descript location and using a small font size—the filenames, project names, or name of the computer code (e.g., macro) used to assist in making a map. By doing this, one can readily go back to the GIS databases of interest, or the computer code; modify an aspect of the composition of the map; and thus facilitate the generation of a new version of the map. Without such guidance, one may find it difficult to remember how a map was originally constructed.

Caveats, Disclaimers, and Warranties
Increasingly, natural resource management organizations are adding more information to the maps they produce to clarify the accuracy of the location of mapped landscape features and to clarify the intended uses of the maps. This information is important in helping users understand the appropriate applications of mapped information and to help them avoid damages and injuries that might result from improper map...

2003 and you examine a map, developed in June 2002, that represents wildlife habitat across several thousand acres of a landscape. Suppose also that the habitat is a function of timber stand conditions and that you are aware that the GIS database describing timber stands was updated in December 2002. If the date is displayed on the map (June 2002), you know that the wildlife habitat being illustrated was determined using an earlier version (not the current one) of the timber inventory data.
use. For example, maps have long served as vital navigational aids to mariners and pilots. The ability to pilot passengers safely depends on the quality of the map information used as a navigational guide. Should a landscape landmark be misplaced or unidentified, the consequences to vehicles navigating based on erroneous data could be dire. As one might imagine, there are a variety of reasons that maps should contain data-quality information, yet the current trend toward providing more of this information is, at least indirectly, a function of litigation becoming more commonplace in society.

A map disclaimer is a statement that embodies the legal position of the map creator with respect to map users. Many map creators use disclaimers to distance themselves from any legal responsibility for damages that could result from the use of their maps. Caveats, similarly, warn others of certain facts in order to prevent the misinterpretation of maps. In general, caveats are less sweeping than disclaimers and may address certain portions or aspects of a map. Warranties, on the other hand, are usually written guarantees of the integrity of a map and of the creator’s responsibility for the repair or replacement of incorrect maps. In practice, disclaimers and caveats are used regularly, but warranties are rarely (if ever) used, in association with maps and GIS databases. Quite often, organizations add disclaimers or caveats to their maps in an attempt to warn users of the limitations of the map content. In some cases, disclaimers are noted directly on the map; in other cases, they are posted on Internet sites devoted to the distribution of maps. Pima County, Arizona, for example, provides a very thorough disclaimer about its products on an Internet site (Pima County [Arizona] Department of Transportation and Flood Control District 2001). The main pieces of information found in caveats and disclaimers are the following:

- Rights reserved via copyright and the permission requirements for modification of the map
- Degree of error found on the map
- Suitability for use
- Liability, or responsibility for errors or omissions (organizations usually assume no responsibility for map users misusing their maps and subsequently incurring losses)
- Contact points (addresses, phone numbers, e-mail addresses)

Caveats and disclaimers vary in form and content from organization to organization. The following are four examples.

The maps on this web site were compiled by Indiana University, Indiana Geological Survey, using data believed to be accurate; however, a degree of error is inherent in all maps. The maps are distributed “AS-IS” without warranties of any kind, either expressed or implied, including but not limited to warranties of suitability to a particular purpose or use. No attempt has been made in either the design or production of the maps to define the limits or jurisdiction of any federal, state, or local government. The maps are intended for use only at the published scale. Detailed on-the-ground surveys and historical analyses of sites may differ from the maps. (Indiana Geological Survey 2001)

Information displayed on our maps was derived from multiple sources. Our maps are only for graphic display and general planning purposes. Inquiries concerning information displayed on our maps, their sources, and intended uses should be directed to: . . . (USDI Bureau of Land Management 2001)

The Orange County Property Appraiser makes every effort to produce and publish the most current and accurate information possible. No warranties, expressed or implied, are provided for the data herein, its use, or its interpretation. The assessed values are NOT certified values and therefore are subject to change before being finalized for ad valorem tax purposes. OCPA’s on-line (cadastral) maps are produced for property appraisal purposes, and are NOT surveys. No warranties, expressed or implied, are provided for the data therein, its use, or its interpretation. (Orange County [Florida] Property Appraiser 2001)

By reading this statement I acknowledge that the data contained in the Geographic Information System (GIS) is subject to constant change and that its accuracy cannot be guaranteed. All data is provided as is, with all faults, and without warranty of any kind, either express or implied, including, but not limited to, the implied purpose. The Town of Blacksburg does not warrant that the functions contained in the GIS data will meet requirements or that the operation of the GIS data will be uninterrupted or error free, or that the GIS data defects will be corrected. I assume the entire risk as to the quality, performance, and usefulness of the data. (Town of Blacksburg [Virginia] 2001)

**MAP TYPES**

The type of map that one develops will be a function of two areas of consideration: (1) the type of data (i.e., point, line, polygon, raster) contained in GIS databases and (2) the message(s) one wishes to communicate to an audience. For example, if the main GIS database used to create a map contains point features, and one wishes to illustrate the differences between the point values, one may want to show the points as dots or graduated symbols (different sizes of points based on the point attribute values). If the main GIS database used to create a map contains line features, one may want to illustrate the differences in the attributes of the lines with different line types. If the features of interest represent areas, GIS databases containing polygons
Thematic maps portray the spatial variation of landscape phenomena and demonstrate one variable or phenomenon at one point in time (Star and Estes 1990). Several types of thematic maps are common. Perhaps the most common type of thematic map is the choropleth map, on which the relative magnitude of attributes of landscape features is illustrated by a range of appropriate values (figure 4.8) and gradations of a color or a set of shading schemes that changes from an empty shaded fill to perhaps a full shaded fill (such as white to light blue to dark blue). The legend is critical when developing choropleth maps, since the colors related to the values must be explicitly described in order to allow users to "fly through the landscape when viewed on a computer screen. The next few sections describe in more detail the most common types of maps developed in natural resource management.

Thematic Maps

Thematic maps often use colors or symbols to describe the areas of a landscape. Features displayed with a combination of color and texture have been shown to be easier to find on maps than features displayed with variations in texture alone (Phillips and Noyes 1982). Thematic maps portray the spatial variation of landscape phenomena and demonstrate one variable or phenomenon at one point in time (Star and Estes 1990).

Data distributions can have many shapes and associated descriptions, but among the most common are normal, random, and even distributions (figure 4.11) (Madej 2001). Normal distributions follow the statistically based representation of values that one would expect to see from most populations or population samples. For this reason, a standard deviation legend classification, with its emphasis on statistical variation from an average, works well. Random distributions are present in data groups in which one cannot discern a pattern to the occurrence of data values. Natural break points can be established by locating subgroupings of random data, creating divisions between sub-groups. Even distributions are data groups in which values do not appear to change very much; one would expect to find a relatively small standard deviation in the data values here. A quantile classification works well for general rule, a minimum of 4, and not more than 6, classifications should be used on a map.

The size (or ranges) of the intervals for each class also have a significant impact on a map's message. Most GIS software programs offer classification techniques to help create legends that take into account the distribution of the data being mapped. An equal interval legend takes into account the range of data values and creates intervals that share an equal distribution of the range (figure 4.10). A quantile distribution puts an equal number of observations into each interval. Intervals might also be created based on how many standard deviations an observation is from the mean or based on natural break points in the distribution of observations. Although these legend tools can save time over manual methods of creating classifications, it is advisable for map developers to examine visually the distribution of the data they are mapping to better understand its character, then decide what legend type would be useful.

### Figure 4.8 Choropleth map.

Basal area (ft²/acre)
- 0–20
- 21–120
- 121–175
- 176–230
- 231+

### Figure 4.9 Range of classes illustrated on a choropleth map.

Basal area (ft²/acre)
- 0–20
- 21–120
- 121–175
- 176–230
- 231+

### Figure 4.10 Equal interval and quantile interval legend classification.

<table>
<thead>
<tr>
<th>Basal area (ft²/acre)</th>
<th>Number of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–50</td>
<td>60</td>
</tr>
<tr>
<td>51–100</td>
<td>40</td>
</tr>
<tr>
<td>101–150</td>
<td>20</td>
</tr>
<tr>
<td>151–200</td>
<td>10</td>
</tr>
<tr>
<td>201+</td>
<td>5</td>
</tr>
</tbody>
</table>

### Figure 4.11 Normal, random, and even distributions of data.

#### Equal area interval

#### Random distribution

#### Even distribution

#### Normal distribution
Thematic Maps

Thematic maps often use colors or symbols to describe the areas of a landscape. Features displayed with a combination of color and texture have been shown to be easier to find on maps than features displayed with variations in texture alone (Phillips and Noyes 1982). Thematic maps portray the spatial variation of landscape phenomena and demonstrate one variable or phenomenon at one point in time (Star and Estes 1990).

Several types of thematic maps are common. Perhaps the most common type of thematic map is the choropleth map, on which the relative magnitude of attributes of landscape features is illustrated by a range of colors or symbols associated with specific values (figure 4.8) and gradations of a color or a set of shading schemes that changes from an empty shaded fill to perhaps a full shaded fill (such as white to light blue to dark blue). The legend is critical when developing choropleth maps, since the colors related to the values must be explicitly described in order for map users to interpret the values. Several design aspects must be addressed when designing a legend. The number of legend classes, or categories, is an important aspect, as too few classes may not contain enough information, but too many classes may present too much detail or result in an overly “busy” map. Sometimes, it is necessary to experiment with several choices to determine which works best (figure 4.9). Dent (1999) provides some guidelines related to this issue. In terms of shades, humans have difficulty in differentiating among more than 11 gray tones. As a general rule, a minimum of 4, and not more than 6, classifications should be used on a map.

The size (or ranges) of the intervals for each class also have a significant impact on a map’s message. Most GIS software programs offer classification techniques to help create legends that take into account the distribution of the data being mapped. An equal interval legend takes into account the range of data values and creates intervals that share an equal distribution of the range (figure 4.10). A quantile distribution puts an equal number of observations into each interval. Intervals might also be created based on how many standard deviations an observation is from the mean or based on natural break points in the distribution of observations. Although these legend tools can save time over manual methods of creating classifications, it is advisable for map developers to examine visually the distribution of the data they are mapping to better understand its character, then decide what legend type would be useful.

Data distributions can have many shapes and associated descriptions, but among the most common are normal, random, and even distributions (figure 4.11) (Madej 2001). Normal distributions follow the statistically based representation of values that one would expect to see from most populations or population samples. For this reason, a standard deviation legend classification, with its emphasis on statistical variation from an average, works well. Random distributions are present in data groups in which one cannot discern a pattern to the occurrence of data values. Natural break points can be established by locating subgroupings of random data, creating divisions between sub-groups. Even distributions are data groups in which values do not appear to change very much; one would expect to find a relatively small standard deviation in the data values here. A quantile classification works well for...
can be categorized into more than one class, the classes are overlapping. Alternatively, the characteristics of landscape features might not fall into any class (might be omitted from a map) because the values fall into a classification level "gap." Either way, the potential problems with the classification must be addressed.

With the increasing capabilities and affordability of color printers and plotters, the use of color to portray legend classifications graphically in maps has become standard. In general, tonal progressions of a single color are useful for illustrating magnitudes of change, with the lighter color tones indicating a lesser quantity of an attribute value than the darker tones. The same effect can be generated with gray tones. Single-color progressions are particularly helpful for representing continuous numeric variables. For nominal data classifications, such as ownership or land use, or numeric data with only a few categories, distinctly different colors or patterns can be used to make certain categories stand out on a map.

Contour maps (figure 4.13) are also a type of thematic map and are sometimes called isoline or isarithmic maps; on these maps, lines or other collections of similar features are used to emphasize gradients or distributions, such as elevations or precipitation levels across a landscape (Star and Estes 1990). The contour interval is the distance between adjacent contour lines. The choice of an interval is important when creating contour maps: tight intervals may result in a cluttered map; wide intervals might misrepresent landscape variation. To reduce clutter on maps, not every contour interval is described with a data value—only those representing significant changes in contour, usually denoted themselves by an interval. For example, although the contour interval between adjacent contour lines may be 100 feet, the only contour lines

represented with data values may be those that represent every 500-foot change in elevation.

Until now, this discussion has focused on maps generated using vector GIS databases, but raster-based maps are also important for displaying data stored in the raster GIS data structure. These maps are very similar to choropleth maps: map developers must classify the values held by the raster pixels, then display them on a map using a legend. Raster-based maps, unless created by rasterizing a vector GIS database, usually have a fuzzier appearance than vector-based maps and, thus, generally represent more heterogeneity across a landscape (figure 4.14).

Dot Density Maps and Cartograms

Dot density maps (figure 4.15) were once commonly used in natural resource management, although less so now. Each dot in a dot density map represents a given value of an attribute. Thus, areas with a greater density of dots are meant to represent areas with greater values of a particular attribute. Graduated circle maps scale the diameters of circle shapes proportionately to an attribute's value to demonstrate differences. Cartograms (figure 4.16) are maps in which more than one attribute of landscape features can be viewed. These maps are also fairly uncommon, given the clutter that can be generated over large landscape areas and the high density of landscape features displayed within a given area (e.g., a multitude of small polygons).
PART I Introduction to Geographic Information Systems, Spatial Databases, and Map Design

CHAPTER 4 Map Design

Figure 4.13 Contour map.

contour maps: Tight intervals may result in a cluttered map; wide intervals might misrepresent landscape variation. To reduce clutter on maps, not every contour interval is described with a data value—only those representing significant changes in contour, usually denoted themselves by an interval. For example, although the contour interval between adjacent contour lines may be 100 feet, the only contour lines represented with data values may be those that represent every 500-foot change in elevation.

Until now, this discussion has focused on maps generated using vector GIS databases, but raster-based maps are also important for displaying data stored in the raster GIS data structure. These maps are very similar to choropleth maps: map developers must classify the values held by the raster pixels, then display them on a map using a legend. Raster-based maps, unless created by rasterizing a vector GIS database, usually have a fuzzier appearance than vector-based maps. For example, al- lthough the contour interval between adjacent contour lines may be 100 feet, the only contour lines of landscape features can be viewed. These maps are also fairly uncommon, given the clutter that can be generated over large landscape areas and the high density of landscape features displayed within a given area (e.g., a multitude of small polygons).

Figure 4.14 Raster map.

Dot Density Maps and Cartograms

Dot density maps (figure 4.15) were once commonly used in natural resource management, although less so now. Each dot in a dot density map represents a given value of an attribute. Thus, areas with a greater density of dots are meant to represent areas with greater values of a particular attribute. Graduated circle maps scale the diameters of circle shapes proportionately to an attribute's value to demonstrate differences. Cartograms (figure 4.16) are maps in which more than one attribute

Figure 4.15 Dot density map.
PART I Introduction to Geographic Information Systems, Spatial Databases, and Map Design

CHAPTER 4 Map Design

Timber Harvest and Management Plan Map
Daniel Pickett Forest - Unit 15

Stand attribute
- Basal area per acre
- Volume per acre (MBF)

Figure 4.16 Cartogram.

Develop map
Get feedback
Map acceptable?
No Edit map
Yes
Map completed

Figure 4.17 Design loop.

THE DESIGN LOOP

Maps usually go through more than one version before they are used by map customers, whether changes are needed based on the map developer's visual assessment of the map or based on customers' suggestions (figure 4.17). Feedback from supervisors and coworkers will allow one to fine-tune maps for reports or activity plans. Besides the aesthetic concerns regarding map type, number of classes shown, and type of scale, map developers should strive to achieve visual balance within their map products. Visual contrast is the most important graphic factor in creating a map (Robinson et al. 1995) and is what sets an object apart from a background (figure 4.18). Sizes, shapes, textures, and colors can all be used to introduce contrast into a map. Contrast will focus the attention of an observer and plays a strong role in determining the clarity and sharpness of a map from the observer's perspective. Map developers must also balance figure-ground relationships, so that the important objects of a map are separated from those that are considered ancillary. In human perception, figures are the objects that are most strongly perceived and remembered, whereas data are less distinctive and less memorable (Dent 1999). Techniques such as figure closure, contrasts with other objects, and object grouping can be used to establish distinctive ground-figure relationships (figure 4.19).

Visual balance is affected by the size of the symbols and features, as well as the location of these in relation to the visual center of the map (figure 4.20). Each iteration in the development of a map can be considered one iteration in the design loop. The number of iterations of a design loop will be a function of one's ability to address a range of visual concerns (visual contrasts, visual balance, legend, etc.), a range of illustrative concerns (showing the correct information), and time constraints (the time remaining before a deadline). It is advisable to start this process by first developing some handwritten notes or bullets that contain the main ideas about the intended map message(s) or purpose and the type of audience likely to view the map. Once these concepts have been identified, it might also be worthwhile to create a hand sketch of the basic map components and how they fit together. At this point, the development of the map within GIS can begin. A well-developed, visually centered map is a reflection of one's professionalism as a natural resource manager (figure 4.21).

COMMON MAP PROBLEMS

There are a number of mistakes, oversights, and omissions that can impair a map's ability to deliver the developer's intended message to an audience. Probably the most important aspect of creating a map is to determine the audience that will be viewing the map. If one's coworkers (other foresters, biologists, etc.) will
Maps usually go through more than one version before they are used by map customers, whether changes are needed based on the... performing objective activities, so that the important object(s) are separated from those that are considered ancillary. In human perception, figures are the objects that are most strongly perceived and remembered, whereas data are less distinctive and less memorable (Dent 1999). Techniques such as figure closure, contrasts with other objects, and object grouping can be used to establish distinctive ground-figure relationships (figure 4.19). Visual balance is affected by the size of the symbols and features, as well as the location of these in relation to the visual center of the map (figure 4.20). Each iteration in the development of a map can be considered one iteration in the design loop. The number of iterations of a design loop will be a function of one’s ability to address a range of visual concerns (visual contrasts, visual balance, legend, etc.), a range of illustrative concerns (showing the correct information), and time constraints (the time remaining before a deadline). It is advisable to start this process by first developing some handwritten notes or bullets that contain the main ideas about the intended map message(s) or purpose and the type of audience likely to view the map. Once these concepts have been identified, it might also be worthwhile to create a hand sketch of the basic map components and how they fit together. At this point, the development of the map within GIS can begin. A well-developed, visually centered map is a reflection of one’s professionalism as a natural resource manager (figure 4.21).

**COMMON MAP PROBLEMS**

There are a number of mistakes, oversights, and omissions that can impair a map’s ability to deliver the developer’s intended message to an audience. Probably the most important aspect of creating a map is to determine the audience that will be viewing the map. If one’s coworkers (other foresters, biologists, etc.) will...
be the primary audience, then perhaps the basic map elements (e.g., a north arrow, bar scale, or locational inset) are not required. This audience may expect to see, instead, more technical information, such as annotation or other descriptive information related to landscape features that demonstrate variation across the landscape. If the audience is a general one, and not familiar with the landscape resources on the map, then it might be important to include basic map elements (e.g., a north arrow, scale bar, and inset) that help the audience orient themselves to the map. If the audience is a scientific one, they may also want to see more detail in the data values, as well as other map guides. Map problems are usually the result of leaving a key element, such as a scale, off a map. Sometimes, these problems result from misjudging the audience; other times, it is simply a matter of oversight. For example, since automatic spell checking processes are available in most word-processing software, map producers sometimes forget that spell checking is usually a manual operation for most GIS map development processes. This requires that map producers carefully read all map text before presenting the final product to their customers.

Excessive detail or clutter can also detract from a map’s message and intent. Most GIS software programs feature an impressive array of mapmaking symbols and tools capable of producing any number of cartographic symbols and other aids. Although many of these tools can be quite helpful, too many objects on a map produce clutter. Excessive detail, especially in maps that are intended to be general information displays, can also result when map developers insert too much text (annotation or labels) onto a map.

It is also common that the output device (e.g., printer or plotter) produces a map with colors that appear slightly different from what the map developer assumes by viewing the computer screen. These problems can be very frustrating, especially after one has painstakingly put together a colored legend scheme and subsequently must make adjustments once a map has been produced. Sometimes, a color mismatch problem can be addressed by choosing a color palette file that is compliant with the output device. Other solutions include using only the primary colors (red, blue, green) or subtractive colors (magenta, cyan, yellow) and creating color schemes that take plotter translations of monitor colors closely into account.

**USGS 7.5 Minute Series Quadrangle Maps**

The most comprehensive reference maps in the United States, in terms of scale and geographic extent, are published by the U.S. Geological Survey (USGS). These maps cover the entire United States, are published at several different scales, contain a wealth of information, and, very important for GIS projects, are available as digital databases that can be used by most GIS software programs that have raster display capabilities. The most detailed of the maps produced by the USGS are the 7.5 Minute (7.5’) Series Quadrangle maps, which have a published map scale of 1:24,000. The 7.5’ refers to the total amount of latitude and longitude, in degrees, on the Earth’s surface that each Quadrangle represents. In some cases, features from the Quadrangle maps, such as hydrography or roads, may be available in a vector format as a digital line graphic (DLG). These Quadrangle maps are a great resource for those who want to learn more about a landscape, and they serve as very useful templates for digitizing or creating GIS databases.

Given the broad availability of the 7.5’ maps, their cartographic detail, and their popularity as a GIS database template for forestry and natural resource applications, we will examine one of these maps and some of the more noteworthy components. Although we will focus on an example using the Corvallis Quadrangle from Oregon, its features should be available on most other 7.5’ maps. In particular, one should look closely at the information that appears at the bottom of the map (figure 4.22). Quadrangle maps also provide information printed along the top margin of the map, but this is generally much more limited and a subset of what one finds along the bottom margin of the map. At the time this book was being developed, a digital copy of this Quadrangle could be downloaded from http://www.reo.gov/gis/gisdata.htm/.

**Lower Right-Hand Corner**

The lower right-hand corner of the Corvallis Quadrangle (figure 4.23) contains a representative scale (1:24,000) and several scale bars with units expressed in miles, feet, and meters. Information is also provided for two contour intervals: the main contour interval of 20 feet (shown by solid lines on the map’s surface) and a secondary contour interval of 5 feet (represented by dashed lines). The reason for this dual depiction is that the Corvallis Quadrangle includes a mixture of moderately sloped forested areas and relatively flat areas where urban and agricultural development has occurred; the dashed 5-foot contours are used for the flatter areas. Below the contour interval descriptions, there is information about where to purchase hardcopies of the Corvallis Quadrangle and the availability of topographic map and symbol descriptions. On the right, a graphic can be found that indicates the location of the Quadrangle relative to the Oregon State border. Below this graphic, some text clarifies that the purple areas of the map were updated with aerial photography.
be the primary audience, then perhaps the basic map elements (e.g., a north arrow, bar scale, or locational inset) are not required. This audience may expect to see, instead, more technical information, such as annotation or other descriptive information related to landscape features that demonstrate variation across the landscape. If the audience is a general one, and not familiar with the landscape resources on the map, then it might be important to include basic map elements (e.g., a north arrow, scale bar, and inset) that help the audience orient themselves to the map. If the audience is a scientific one, they may also want to see more detail in the data values, as well as other map guides. Map problems are usually the result of leaving a key element, such as a scale, off a map. Sometimes, these problems result from misjudging the audience; other times, it is simply a matter of oversight. For example, since automatic spell checking processes are available in most word-processing software, map producers sometimes forget that spell checking is usually a manual operation for most GIS map development processes. This requires that map producers carefully proofread all maps before presenting the final product to their customers.

Excessive detail or clutter can also detract from a map's message and intent. Most GIS software programs feature an impressive array of mapmaking symbols and tools capable of producing any number of cartographic symbols and other aids. Although many of these tools can be quite helpful, too many objects on a map produce clutter. Excessive detail, especially in maps that are intended to be general information displays, can also result when map developers insert too much text (annotation or labels) onto a map. It is also common that the output device (e.g., printer or plotter) produces a map with colors that appear slightly different from what the map developer assumes by viewing the computer screen. These problems can be very frustrating, especially after one has painstakingly put together a colored legend scheme and subsequently must make adjustments once a map has been produced. Sometimes, a color mismatch problem can be addressed by choosing a color palette file that is compliant with the output device. Other solutions include using only the primary colors (red, blue, green) or subtractive colors (magenta, cyan, yellow) and creating color schemes that take plotter translations of monitor colors closely into account.

USGS 7.5 MINUTE SERIES QUADRANGLE MAPS

The most comprehensive reference maps in the United States, in terms of scale and geographic extent, are published by the U.S. Geological Survey (USGS). These maps cover the entire United States, are published at several different scales, contain a wealth of information, and, very important for GIS projects, are available as digital databases that can be used by most GIS software programs that have raster display capabilities. The most detailed of the maps produced by the USGS are the 7.5 Minute (7.5') Series Quadrangle maps, which have a published map scale of 1:24,000. The 7.5' refers to the total amount of latitude and longitude, in degrees, on the Earth's surface that each Quadrangle represents. In some cases, features from the Quadrangle maps, such as hydrography or roads, may be available in a vector format as a digital line graphic (DLG). These Quadrangle maps are a great resource for those who want to learn more about a landscape, and they serve as very useful templates for digitizing or creating GIS databases.

Given the broad availability of the 7.5' maps, their cartographic detail, and their popularity as a GIS database template for forestry and natural resource applications, we will examine one of these maps and some of the more noteworthy components. Although we will focus on an example using the Corvallis Quadrangle from Oregon, its features should be available on most other 7.5' maps. In particular, one should look closely at the information that appears at the bottom of the map (figure 4.22). Quadrangle maps also provide information printed near the top margin of the map, but this is generally much more limited and a subset of what one finds along the bottom margin of the map. At the time this book was being developed, a digital copy of this Quadrangle could be downloaded from http://www.reo.gov/gis/gisdata.htm/.

Lower Right-Hand Corner

The lower right-hand corner of the Corvallis Quadrangle (figure 4.23) contains a representative scale (1:24,000) and several scale bars with units expressed in miles, feet, and meters. Information is also provided for two contour intervals: the main contour interval of 20 feet (shown by solid lines on the map's surface) and a secondary contour interval of 5 feet (represented by dashed lines). The reason for this dual depiction is that the Corvallis Quadrangle includes a mixture of moderately sloped forested areas and relatively flat areas where urban and agricultural development has occurred; the dashed 5-foot contours are used for the flatter areas. Below the contour interval descriptions, there is information about where to purchase hard copies of the Corvallis Quadrangle and the availability of topographic map and symbol descriptions. On the right, a graphic can be found that indicates the location of the Quadrangle relative to the Oregon State border. Below this graphic, some text clarifies that the purple areas of the map were updated with aerial photography captured in 1982 (and hence edited in 1986). Moving to just below the bottom right-hand corner of the map, one finds a legend for road map symbols. The name of the map is listed (CORVALLIS, ORE.), and the map is described as the bottom right-hand corner (SE/4) of the 15' Corvallis Quadrangle. The OHIO code description, sometimes referred to as the USGS Map Reference Code, is listed as 44123-E3. This means that the map is located in a block of geographic latitude and longitude that begins at the intersection of 44° latitude and 123° longitude (USDI U.S. Geological Survey 1995). Each block of latitude and longitude can contain up to 64 7.5' Quadrangle maps that comprise an eight-by-eight matrix. Letters are used for A to H to denote rows starting from the corner of the latitude and longitude intersection and moving upward. Numbers are used from 1 to 8, moving westward to signify columns. Thus, the Corvallis Quadrangle is located in the matrix at the intersection of the 5th row and the 3rd column (figure 4.24). This OHIO code system is used by many map distributors to identify the relative location of quadrangles. The year of the original aerial

Figure 4.22 Corvallis Quadrangle with neatlines around map areas to be described in detail.
Figure 4.23 Lower right-hand corner of the Corvallis Quadrangle.

Lower Left-Hand Corner

The lower left-hand corner of the map (figure 4.25) states that the map was produced by the USGS with control or reference points established by the USGS, the U.S. Coast and Geodetic Survey, and the State of Oregon. Mapped surfaces were taken from 1967 aerial photography and were field checked in 1969. Projection information is then listed, and the base surface is described as a polyconic projection, NAD27, using the Oregon State Plane North Coordinate System. A line follows, which describes the coloring of the UTM coordinates listed around the perimeter of the map and the UTM zone (10) that was used. Instructions for converting the mapped surface from NAD27 to NAD83 are also given. This information is useful for potential coordinate conversions in a GIS. In addition, text describes that only landmark buildings are shown in map areas that are tinted red. Landmark buildings are those that serve the public, have cultural or historical significance, or are unusually large in relation to surrounding buildings.

To the right of these statements, a graphic of the map’s orientation to several definitions of north is shown, and text below the graphic explains that the orientation is from the map’s center. The longest north line is topped by a star symbol and refers to astronomic north. The line to the left of astronomic north shows the magnetic declination (19°), relative to astronomic north, that existed in 1986. Since magnetic north can fluctuate from year to year (small daily shifts are also possible), the date of the measurement is important for those who wish to convert their data to match the map’s projection.

Geographic coordinates appear at the corner of the mapped surface, and the UTM coordinate abbreviations are listed. A full listing of state plane coordinates (NAD27) appears and is marked by hatch lines to the north (320,000 feet) and east (1,260,000 feet) of this corner. Full state plane coordinates are also listed along the upper right-hand corner. Unmarked hash marks around the rest of the map’s perimeter denote gradations of the state plane coordinates. Periodically, range and township divisions appear as longer dashed lines on the map’s surface. Along the latitudinal axis of figure 4.25, one can see R. 6 W. and R. 5 W. This signifies the division between Range 6 and 5, west of the reference meridian (Willamette) that was used for creating the Public Land Survey System (PLSS, described
photography (1969) that was used to create the map is listed, as is the last revision year (1986). The bottom corner of the mapped area has a set of geographic coordinates (44°30' and 123°15'), which describe its location. Just to the east and slightly north of this corner, a cross appears. These crosses are in similar locations relative to all four mapped area corners and demonstrate how the mapped surface corners can be adjusted to switch the datum of the map's projection from NAD27 to NAD83 (NAD is short for North American Datum). A full universal transverse Mercator (UTM) easting (479,000 m) is found just west of this corner and a full UTM northing (4,928,000 m) to the north. Full UTM coordinates are also listed. This information is useful for potential coordinate conversions in a GIS. In addition, text describes that only landmark buildings are shown in map areas that are tinted red. Landmark buildings are those that serve the public, have cultural or historical significance, or are unusually large in relation to surrounding buildings.

To the right of these statements, a graphic of the map's orientation to several definitions of north is shown, and text below the graphic explains that the orientation is from the map's center. The longest north line is topped by a star symbol and refers to astronomic north. The line to the right of astronomic north refers to grid north (GN) and is oriented 0°13’ (0.22°) west of astronomic north. Grid north is the direction in which the Oregon State Plane Coordinate System is referenced. The line to the right of astronomic north shows the magnetic declination (19°), relative to astronomic north, that existed in 1986. Since magnetic north can fluctuate from year to year (small daily shifts are also possible), the date of the measurement is important for those who wish to convert their data to match the map's projection.

Geographic coordinates appear at the corner of the mapped surface, and the UTM coordinate abbreviations are listed. A full listing of state plane coordinates (NAD27) appears and is marked by hatch lines to the north (320,000 feet) and east (1,260,000 feet) of this corner. Full state plane coordinates are also listed along the upper right-hand corner. Unmarked hash marks around the rest of the map's perimeter denote gradations of the state plane coordinates. Periodically, range and township divisions appear as longer dashed lines on the map's surface. Along the latitudinal axis of figure 4.25, one can see R. 6 W. and R. 5 W. This signifies the division between Range 6 and 5, west of the reference meridian (Willamette) that was used for creating the Public Land Survey System (PLSS, described
Figure 4.25 Lower left-hand corner of the Corvallis Quadrangle.

in chapter 2) for Oregon. Larger numbers appear on the mapped surface and describe the boundaries between sections and donation land claims (DLCs). Most of the western United States was originally divided according to the PLSS. The PLSS split regions of the country in a grid of townships (approximately 6-by-6-mile blocks created by the intersections of township and range lines) that were created from a reference meridian, with townships further divided into sections measuring approximately 1 square mile. Section numbers range from 1 to 36 in almost all PLSS states, although one might find an occasional section numbered 37 where measurement irregularities warranted adjustments to the PLSS. Some states, including Oregon, Florida, and New Mexico, had adopted less rigorous land measurement systems that superseded the PLSS. Through these systems, settlers could stake claims to lands, and these systems were generally referred to as DLCs. DLC boundaries are numbered starting with 37.

In general, green shading (gray in the black-and-white image of figure 4.25) is used to represent forested or natural areas, and no shading is used to represent developed areas. Roads, streams, and other cultural and natural landscape features are also visible throughout the map.

National Map Accuracy Standards

According to the information illustrated in figure 4.23, the Corvallis Quadrangle map complies with the National Map Accuracy Standards (NMAS). These standards were originally developed by the U.S. Bureau of the Budget in 1941, so that guidelines would be available for the establishment of horizontal and vertical map accuracy at multiple scales. The guidelines were also intended to help protect and inform consumers about the quality of the map products they acquired. The guidelines assume that organizations that claim adherence to NMAS guidelines are responsible for ensuring compliance. The NMAS was last revised in 1947 (Thompson 1979).

The guidelines (figure 4.26) provide horizontal accuracy standards for map scales larger than 1:20,000 and for scales at 1:20,000 or smaller. For the larger map scales, no more than 10 percent of the points verified shall be in error by 1/30th of an inch, as measured on the map surface. For smaller scale maps, this tolerance is 1/50th of an inch. The Corvallis Quadrangle falls into the latter category. To test for NMAS compliance, locations or elevations from map points are compared with their actual measurements, where locations or elevations have been derived by highly accurate ground surveys. Within these comparisons, only 10 percent of the points can be in error by more than the tolerance. Table 4.1 describes the tolerances in relation to some of the more common map scales. For the Corvallis Quadrangle, this threshold would be 40 feet, indicating that not more than 10 percent of the tested map points should differ from their actual locations by more than 40 feet. Vertical accuracy standards are applied by using half the contour interval as a benchmark. For vertical accuracy of the primary contour lines (20' intervals) of the Corvallis Quadrangle, the standard indicates that 90 percent of the elevation points checked along the contour lines should not be in error by more than 10 feet.

Typically, on USGS 7.5 Minute Quadrangles, 28 points are examined for accuracy verification, representing a very small portion of the population of map points. It is also worth noting that these points are not randomly selected but, rather, represent locations that are readily visible on the photography from which the map was created, such as road intersections, bridges, and other noteworthy structures. Thus, one would expect that the points represent the mapped areas where the photogrammetric methods used to create the map were most reliable. It is also worth noting that 10 percent of those points could be off by any distance, and the resulting map would still be NMAS compliant. So, even though one is assured compliance with a published standard, the potential for errors related to the accuracy of the locations of landscape features can still be significant.

### Table 4.1 Map Scales and Associated National Map Accuracy Standards for Horizontal Accuracy

<table>
<thead>
<tr>
<th>Scale</th>
<th>Standard (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1,200</td>
<td>±3.33</td>
</tr>
<tr>
<td>1:2,400</td>
<td>±6.67</td>
</tr>
<tr>
<td>1:4,800</td>
<td>±13.33</td>
</tr>
<tr>
<td>1:10,000</td>
<td>±27.78</td>
</tr>
<tr>
<td>1:12,000</td>
<td>±33.33</td>
</tr>
<tr>
<td>1:24,000</td>
<td>±40.00</td>
</tr>
<tr>
<td>1:63,360</td>
<td>±105.60</td>
</tr>
<tr>
<td>1:100,000</td>
<td>±166.67</td>
</tr>
</tbody>
</table>

**SUMMARY**

Maps are a method used to convey ideas about the spatial location of resources and, when well developed, are an effective way of communicating ideas. This chapter presented a variety of components that can be used to develop an effective map, such as legends, scale bars, and types of maps. The representation of these components on a map may be important to customers of the map. For example, certain components...
National Map Accuracy Standards

According to the information illustrated in figure 4.23, the Corvallis Quadrangle map complies with the National Map Accuracy Standards (NMAS). These standards were originally developed by the U.S. Bureau of the Budget in 1941, so that guidelines would be available for the establishment of horizontal and vertical map accuracy at multiple scales. The guidelines were also intended to help protect and inform consumers about the quality of the map products they acquired. The guidelines assume that organizations that claim adherence to NMAS guidelines are responsible for ensuring compliance. The NMAS was last revised in 1947 (Thompson 1979).

The guidelines (figure 4.26) provide horizontal accuracy standards for map scales larger than 1:20,000 and for scales at 1:20,000 or smaller. For the larger map scales, no more than 10 percent of the points verified shall be in error by 1/2 of an inch, as measured and other noteworthy structures. Thus, one would expect that the points represent the mapped areas where ecological soundings or elevations from map points are compared with their actual measurements, where locations or elevations have been derived by highly accurate ground surveys. Within these comparisons, only 10 percent of the points can be in error by more than 10 feet.

Typically, on USGS 7.5 Minute Quadrangles, 28 points are examined for accuracy verification, representing a very small portion of the population of map points. It is also worth noting that these points are not randomly selected but, rather, represent locations that are readily visible on the photography from which the map was created, such as road intersections, bridges, and other noteworthy structures. Thus, one would expect that the points represent the mapped areas where the photogrammetric methods used to create the map were most reliable. It is also worth noting that 10 percent of these points could be off by any distance, and the resulting map would still be NMAS compliant. So, even though one is assured compliance with a published standard, the potential for errors related to the accuracy of the locations of landscape features can still be significant.

SUMMARY

Maps are a method used to convey ideas about the spatial location of resources and, when well developed, are an effective way of communicating ideas. This chapter presented a variety of components that can be used to develop an effective map, such as legends, scale bars, and types of maps. The representation of these components on a map may be important to customers of the map. For example, certain components numbers range from 1 to 36 in almost all PLSS states, although one might find an occasional section numbered 37 where measurement irregularities warranted adjustments to the PLSS. Some states, including Oregon, Florida, and New Mexico, had adopted less rigorous land measurement systems that superceded the PLSS. Through these systems, settlers could stake claims to lands, and these systems were generally referred to as DLCs. DLC boundaries are numbered starting with 51. In general, green shading (gray in the black-and-white image of figure 4.25) is used to represent forested or natural areas, and no shading is used to represent developed areas. Roads, streams, and other cultural and natural landscape features are also visible throughout the map.

Table 4.1 Map Scales and Associated National Map Accuracy Standards for Horizontal Accuracy

<table>
<thead>
<tr>
<th>Scale</th>
<th>Standard (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1,200</td>
<td>±3.33</td>
</tr>
<tr>
<td>1:2,400</td>
<td>±6.67</td>
</tr>
<tr>
<td>1:4,800</td>
<td>±13.33</td>
</tr>
<tr>
<td>1:10,000</td>
<td>±27.78</td>
</tr>
<tr>
<td>1:12,000</td>
<td>±33.33</td>
</tr>
<tr>
<td>1:24,000</td>
<td>±40.00</td>
</tr>
<tr>
<td>1:63,360</td>
<td>±105.60</td>
</tr>
<tr>
<td>1:100,000</td>
<td>±166.67</td>
</tr>
</tbody>
</table>

Figure 4.25 Lower left-hand corner of the Corvallis Quadrangle.
United States National Map Accuracy Standards

With a view to the utmost economy and expedition in producing maps which fulfill not only the broad needs for standard or principal maps, but also the reasonable particular needs of individual agencies, standards of accuracy for published maps are defined as follows:

1. **Horizontal accuracy.** For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is well defined will also be determined by what is plottable on the scale of the map within 1/100 inch. Thus while the intersection of two road or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, etc.

2. **Vertical accuracy**, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

3. The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy. Tests shall be made by the producing agency, which shall also determine which of its maps are to be tested, and the extent of such testing.

4. **Published maps meeting these accuracy requirements** shall note this fact on their legends, as follows: "This map complies with National Map Accuracy Standards."

5. **Published maps whose errors exceed those aforestated** shall omit from their legends all mention of standard accuracy.

6. When a published map is a considerable enlargement of a map drawing (manuscript) or of a published map, that fact shall be stated in the legend. For example, "This map is an enlargement of a 1:20,000-scale map drawing," or "This map is an enlargement of a 1:24,000-scale published map."

7. To facilitate ready interchange and use of basic information for map construction among all Federal mapmaking agencies, manuscript maps and published maps, wherever economically feasible and consistent with the uses to which the map is to be put, shall conform to latitude and longitude boundaries, being 15 minutes of latitude and longitude, or 7.5 minutes, or 3-3/4 minutes in size.

Figure 4.26 National map accuracy standards.

of maps are required when developing maps for co-workers or for others internal to a natural resource management organization; certain components are required when developing maps for external clients (e.g., when submitting a harvest plan to a state agency); and certain components are required when developing a map for personal use. There is no one correct format. One should, however, have an understanding of the options available for map products and of the intended audience. Each map developed reflects one's professionalism as a natural resource manager.
4.1 Age class distribution of the Daniel Pickett Forest. The manager of the Daniel Pickett Forest would like you to produce a map to illustrate the age class distribution of the forest to the president of the company. Develop a thematic map showing five age classes: 0–20 years old, 21–40, 41–60, 61–80, and 80+.

4.2 Age class distribution of the Brown Tract. The manager of the Brown Tract, Becky Blaylock, needs an age class distribution map for an annual report she is developing. Produce a map showing five age classes: 0–20 years old, 21–40, 41–60, 61–80, and 80+.

4.3 Owl nest locations on the Daniel Pickett Forest. The wildlife biologist associated with the Daniel Pickett Forest needs a map illustrating the spotted owl (Strix occidentalis) nest locations on the forest. Produce a map illustrating the two locations.

4.4 Stream types of the Daniel Pickett Forest. The hydrologist associated with the Daniel Pickett Forest needs a map illustrating the different stream types, in order to direct a summer crew to the locations to be surveyed for fish species and habitat conditions.

4.5 Potential harvest unit. The land manager of the Daniel Pickett Forest is considering a timber sale in unit number 13 on the Daniel Pickett Forest. He would like you to produce a map indicating that unit 13 is a proposed harvest area and display the road and stream systems in relation to the unit.

4.6 Brown Tract trail system. The manager of the Brown Tract, Becky Blaylock, would like you to develop a map illustrating the trail system on the Brown Tract, highlighting both the authorized and unauthorized trails. This map will be used by recreationists who visit the forest. Include as reference information on the map the road system and contour elevations.

4.7 Culvert installation dates. The road engineer associated with the Daniel Pickett Forest, Bob Packard, is in the process of developing a culvert replacement plan. He would like you to develop a map illustrating the road system, the culverts, and the culvert installation dates for the Daniel Pickett property.

4.8 Quadrangle challenge. Locate a USGS 7.5 Minute Quadrangle near your work or school location.

a. What is the name of the Quadrangle?

b. When was the map originally compiled?

c. If the map has been updated, when was it updated?

d. What is the OHIO code description of the map?

e. When was the topography developed?

f. How much magnetic declination exists in the map?

4.9 Disclaimers, caveats, and warranties. You work for an agency that has developed a statewide streams GIS database. At one of your regular staff meetings, the discussion shifts to this GIS database and the notion of associating a disclaimer, caveat, or warranty with the GIS database. You gather from the conversation that the group is very confused about the use of the terms disclaimer, caveat, and warranty. What guidance can you provide to help them understand the differences among the terms and how the terms might be used in relation to the streams GIS database?