EIGHTH EDITION

Mastering ArcGIS

McGraw Hill Education

MARIBETH H. PRICE

Eighth Edition

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Mastering ArcGIS

Mc Graw Hill Education

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Preface

Welcome to *Mastering ArcGIS*, a detailed primer on learning the ArcGIS™ software by ESRI®, Inc. This book is designed to offer everything you need to master the basic elements of GIS.

Notice: ArcGIS™, ArcMap™, ArcCatalog™, ArcGIS Desktop™, ArcInfo Workstation™, and the other program names used in this text are registered trademarks of ESRI, Inc. The software names and the screen shots used in the text are reproduced by permission. For ease of reading only, the ™ symbol has been omitted from the names; however, no infringement or denial of the rights of ESRI® is thereby intended or condoned by the author.

What's new in the eighth edition?

The primary goals for this edition included updating many of the data sets with more recent versions, particularly those utilizing population information, as well as updating the text to work with ArcGIS Desktop version 10.5.1. The interface continues to remain fairly stable, and only minor adjustments are needed. This edition should work equally well with versions 10.2 to 10.5. A few minor changes in command names or buttons are found, and a few new bugs complicate matters here and there, but most users should be able to follow along and make any necessary adjustments. It is expected that the interface will remain stable while ESRI turns its focus to developing the new desktop program, ArcGIS Pro.

I would like to thank the many people who have used and commented on this book, and I hope that it continues to serve their needs in the rapidly evolving world of GIS.

Looking ahead

ESRI released a completely redesigned ArcGIS Desktop product in late fall 2014, called ArcGIS Pro. It has a 64-bit, multithreaded architecture, uses ribbon-style menus, integrates 2D and 3D applications, and is closely tied to ArcGIS Online. A new textbook focused on ArcGIS Pro is being developed for the *Mastering ArcGIS* series. ArcMap and ArcCatalog will exist side-by-side with this new program for many years yet, and we anticipate keeping an edition of *Mastering ArcGIS* in print as long as needed for those continuing to use them.

Previous experience

This book assumes that the reader is comfortable using Windows™ to carry out basic tasks such as copying files, moving directories, opening documents, exploring folders, and editing text and word processing documents. Previous experience with maps and map data is also helpful. No previous GIS experience or training is necessary to use this book.

Elements of the package

This learning system includes a textbook and web site, including

- Fourteen chapters on the most important capabilities of ArcGIS
- Comprehensive tutorials in every chapter to learn the skills, with each step demonstrated in a video clip
- A set of exercises, map documents, and data for practicing skills independently
- Reference sections on skills with video clips demonstrating each one

This book assumes that the student has access to ArcGIS Desktop Basic (formerly ArcView). A few optional topics are introduced that require an ArcGIS Desktop Standard (formerly ArcEditor) license. The Spatial Analyst extension is required for Chapter 11.

Philosophy

This text reflects the author's personal philosophies and prejudices developed from 20 years of teaching GIS at an engineering school. The main goal is not to train geographers but to provide students in any field with GIS skills and knowledge. It is assumed that most students using this book already have a background of discipline-specific knowledge and skills upon which to draw and are seeking to apply geospatial techniques within their own knowledge domains.

- **GIS is best learned by doing it, not by studying it.** The laboratory is THE critical component of the book, and theory is introduced sparingly and integrated with experience. Hence, this book is heavy on experience and lighter on theory.
- **Independent work and projects are critical to learning GIS.** This book includes a wealth of exercises in which the student must find solutions independently without a cookbook recipe of steps. A wise instructor will also require students to develop an independent project.

Chapter sequence

The book contains an introduction and 14 chapters. Each chapter includes roughly one week's work for a three-credit semester course. This book intentionally contains more material than the average GIS class can cover during a single semester; instructors may choose what to emphasize.

An introductory chapter describes GIS and gives some examples of how it is used. It also provides an overview of GIS project management and how to develop a project. Chapters 1–11 follow a roughly project-based sequence: data compilation, data exploration and mapping, tables and basic editing, and analysis. These chapters are the core of an introductory GIS class and, by the end of it, students should have little difficulty developing and carrying out an independent GIS project. The final chapters introduce several more advanced topics in data management.

Chapter layout

Each chapter is organized into the following sections:

- **Concepts:** provides basic background material for understanding geographic concepts and how they are specifically implemented within ArcGIS. Most chapters have two sections, one (GIS Concepts) covering general GIS concepts and theory, and another (About ArcGIS) covering the specific implantation of those concepts within ArcGIS Desktop. A set of review questions and important terms follows the concepts section.

- **Tutorial:** contains a step-by-step tutorial demonstrating the concepts and skills. The tutorials begin with detailed instructions, which gradually become more general as mastery is built. Every step in the tutorial is demonstrated by accompanying video clips.

- **Exercises:** presents a series of problems to build skill in identifying the appropriate techniques and applying them without step-by-step help. Through these exercises, the student builds an independent mastery of GIS processes. Brief solution methods are included for all exercises, and maps of the results are shown when applicable. A full answer and methods document is available for instructors at the McGraw-Hill Instructor web site.

The web site also contains all the data needed to follow the tutorials and complete the exercises.

Instructors should use judgment in assigning exercises, as the typical class would be stretched to complete all the exercises in every chapter. Very good students can complete the entire chapter in 3–6 hours, most students would need 6–8 hours, and a few students would require 10 or more hours. Students with more computer experience generally find the material easier than others.

Using this text

In working through this book, the following sequence of steps is suggested:

- READ through the Concepts sections to get familiar with the principles and techniques.
- ANSWER the Chapter Review Questions to test comprehension of the material.
- WORK the Tutorial section for a step-by-step tutorial and explanation of key techniques.
- REREAD the Concepts section to reinforce the ideas.
- PRACTICE by doing the Exercises.

Using the tutorial

The tutorial provides step-by-step practice and introduces details on how to perform specific tasks. Students should be encouraged to think about the steps as they are performed and not just race to get to the end.

It is important to follow the directions carefully. Skipping a step or doing it incorrectly may result in a later step not working properly. Saving often will make it easier to go back and correct a mistake in order to continue. Occasionally, a step will not work due to differences between computer systems or software versions. Having an experienced user nearby to identify the problem can help. If one isn't available, however, just skip the step and move on without it.

Using the videos

The web site contains two types of videos. The Tutorial Videos demonstrate each step of the tutorial. They are numbered in the text for easy reference. The Skills Reference Videos show how to perform generic tasks, such as deleting a file. The videos are intended as an alternate learning strategy. It would be tedious to watch all of them. Instead, use them in the following situations:

- When the student does not understand the written instructions or cannot find the correct menu or button
- When a step cannot be made to work properly
- When a reminder is needed to do a previously learned skill in order to complete a step
- When a student finds that watching the videos enhances learning

As you work through a chapter, keep the web site video listing on the screen, and click the appropriate link to see a video. The tutorial clips are distinguished by numbered steps and the Skills Reference Videos by their headings.

Using video and data components

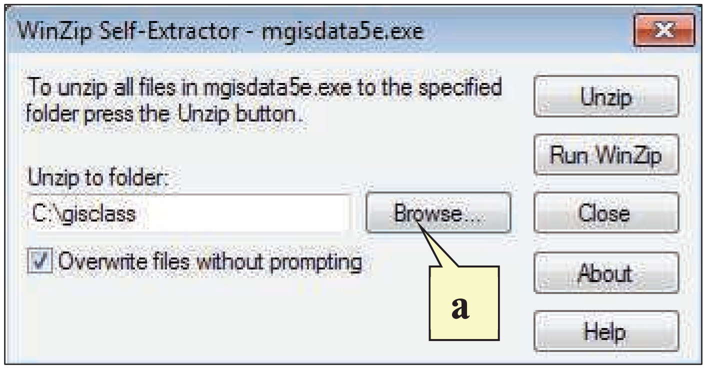
Using the videos:

The videos are available for download from the book web site. Each chapter may be downloaded separately. The videos for Chapter 1 must be downloaded first, for they contain the instructions and folder hierarchy needed for the subsequent chapters. Please review the instructions in the Chapter 1 download before downloading the rest of the videos.

To install the training data:

The mgisdata.exe archive contains a folder with the documents and data needed to do the tutorials and exercises. The student must copy this folder to the computer's hard drive. If multiple people are using the same computer to complete the activities in this book, then each person should make a copy of the data in a separate folder. The data in the exe archive are a self-extracting zip file that requires approximately 350 MB of disk space. Follow these instructions to install the data:

- Click on the link to Install Data. If a dialog window appears asking whether to Run or Save the data, choose Run.
- When a dialog box appears asking whether to Open or Save the data, choose Open. Don't choose Save because it will only copy the data archive instead of extracting it.
- Click the Browse button to set the folder to which to extract the data (a). The data will be placed in a folder called mgisdata in whatever location you choose. In other words, if you select C:\gisclass as the target folder, then the data will be placed in C:\gisclass\mgisdata.



Installing the training data

Source: WinZip Self-Extractor

- Click Start to begin installing the data. It may take several minutes. Wait until you see the Finished window and then click OK.

System requirements

To use the tutorials and do the exercises in this book, the student must have access to a computer with the following characteristics:

Minimum hardware:

PC-Intel™-platform computer with 2.2-GHz processor or better and 2 GB RAM

Suitable sound/graphics card with 24-bit color depth and 1024 × 768 minimum screen

Software:

Windows 10 (Home or Pro), Windows 8 (Basic, Professional, Enterprise), Windows 7™ (Ultimate, Enterprise, Professional, Home Premium), Windows Vista™ (Ultimate, Enterprise, Business, Home Premium), Windows 2000™, or Windows XP™ (Home Edition, Professional); requires Microsoft .NET framework to be installed.

A web browser, such as Edge, Chrome, Firefox, or Internet Explorer, or Microsoft® Word

A zip utility such as WinZip or 7zip

A media player that is able to display the .mp4 video format (such as Windows Media Player 12 [Windows 7 only] or QuickTime™)

ArcGIS Desktop™ 10.2 or higher (Basic Level); Standard Level and Spatial Analyst extension required for some exercises

For more information, please consult: http://www.esri.com/software/arcgis/arcgis-for-desktop/system-requirements

Internet access is required for ArcGIS installation and for exercises requiring use of ArcGIS Online. Exercises do not require an ArcGIS Online account, although a public or organizational subscription will provide access to more capabilities and content.

For assistance in acquiring or installing these components, contact your system administrator, hardware/software provider, or local computer store.

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I would like to thank many people who made this book possible. Governor Janklow of South Dakota funded a three-month summer project in 2000 that got the book started, as part of his Teaching with Technology program. Many students in my GIS classes between 2000 and 2014 tested the text and exercises and helped immensely in making sure the tutorials were clear and worked correctly. Reviewers of previous editions, including Richard Aspinall, Joe Grengs, Tom Carlson, Susan K. Langley, Henrietta Loustsen, Xun Shi, Richard Lisichenko, John Harmon, Michael Emch, Jim Sloan, Sharolyn Anderson, Talbot Brooks, Qihao Weng, Jeanne Halls, Mark Leipnik, Michael Harrison, Ralph Hitz, Olga Medvedkov, James W. Merchant, Raymond L. Sanders, Jr., Yifei Sun, Fahui Wang, Michael Haas, Jason Kennedy, Dafna Kohn, Jessica Moy, James C. Pivirotto, Peter Price, Judy Sneller, Dave Verbyla, Birgit Mühlenhaus, Jason Duke, Darla Munroe, Wei-Ning Xiang, L. Joe Morgan, Samantha Arundel, Christopher A. Badurek, Tamara Biegas, John E. Harmon, Michael Hass, Nicholas Kohler, David Long, Jaehyung Yu, Sarah Battersby, Gregory S. Bohr, Kelly R. Dubure, Colleen Garrity, Raymond Greene, Eileen Johnson, James Leonard, and Tao Tang provided detailed and helpful comments, and the book is better than it would have been without their efforts. I also thank the reviewers who provided valuable advice for the seventh edition.

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Introduction

What Is GIS?

Objectives

- Developing a basic understanding of what GIS is, its operations, and its uses
- Getting familiar with GIS project management
- Learning to plan a GIS project
- Finding resources to learn more about GIS

Concepts

What is GIS?

GIS stands for Geographic Information System. In practical terms, a GIS is a set of computer tools that allows people to work with data that are tied to a particular location on the earth. Although many people think of a GIS as a computer mapping system, its functions are broader and more sophisticated than that. A GIS is a database that is designed to work with map data.

Consider the accounting department of the local telephone company. They maintain a large computer database of their customers, in which they store the name, address, phone number, type of service, and billing information for each customer. This information is only incidentally tied to where customers live; they can carry out most of the important functions (billing, for example) without needing to know where each house is. Of course, they need to have addresses for mailing bills, but it is the post office that worries about where the houses actually are. This type of information is called **aspatial data**, meaning that it is not tied, or is only incidentally tied, to a location on the earth's surface.

Employees of the service department, however, need to work with **spatial data** to provide the telephone services. When hundreds of people call in after a power outage, the service department must analyze the distribution of the calls and isolate the location where the outage occurred. When a construction company starts work on a street, workers must be informed of the precise location of buried telephone cables. If a developer builds a new neighborhood, the company must be able to determine the best place to tie into the existing network so that the services are efficiently distributed from the main trunk lines. When technicians prepare lists of house calls for the day, they need to plan the order of visits to minimize the amount of driving time. In these tasks, location is a critical aspect of the job, and the information is spatial.

In this example, two types of software are used. The accounting department uses special software called a *database management system*, or *DBMS*, which is optimized to work with large volumes of aspatial data. The service department needs access to a database that is optimized for working with spatial data, a Geographic Information System. Because these two types of software are related, they often work together, and they may access the same information. However, they do different things with the data.

A GIS is built from a collection of hardware and software components.

- ***A computer hardware platform.*** Due to the intensive nature of spatial data storage and processing, a GIS was once limited to large mainframe computers or expensive workstations. Today, it can run on a typical desktop personal computer.
- ***GIS software.*** The software varies widely in cost, ease of use, and level of functionality but should offer at least some minimal set of functions, as described in the next few paragraphs. In this book, we study one particular package that is powerful and widely used, but others are available and may be just as suitable for certain applications.
- ***Data storage.*** Some projects use only the hard drive of the GIS computer. Other projects may require more sophisticated solutions if large volumes of data are being stored or multiple users need access to the same data sets. Today, many data sets are stored in digital warehouses and accessed by many users over the Internet. Compact disc writers and/or USB portable drives are highly useful for backing up and sharing data.
- ***Data input hardware.*** Many GIS projects require sophisticated data entry tools. Digitizer tablets enable the shapes on a paper map to be entered as features in a GIS data file. Scanners create digital images of paper maps. An Internet connection provides easy access to large volumes of GIS data. High-speed connections are preferred, as GIS data sets may constitute tens or hundreds of megabytes or more.
- ***Information output hardware.*** A quality color printer capable of letter-size prints provides the minimum desirable output capability for a GIS system. Printers that can handle map-size output (36 in. × 48 in.) will be required for many projects.
- ***GIS data.*** Data come from a variety of sources and in a plethora of formats. Gathering data, assessing their accuracy, and maintaining them usually constitutes the longest and most expensive part of a GIS project.
- ***GIS personnel***. A system of computers and hardware is useless without trained and knowledgeable people to run it. The contribution of professional training to successful implementation of a GIS is often overlooked.

GIS software varies widely in functionality, but any system claiming to be a GIS should provide the following functions at a minimum:

- ***Data entry*** from a variety of sources, including digitizing, scanning, text files, and the most common spatial data formats; ways to export information to other programs should also be provided
- ***Data management*** tools, including tools for building data sets, editing spatial features and their attributes, and managing coordinate systems and projections
- ***Thematic mapping*** (displaying data in map form), including symbolizing map features in different ways and combining map layers for display
- ***Data analysis*** functions for exploring spatial relationships in and between map layers
- ***Map layout*** functions for creating soft and hard copy maps with titles, scale bars, north arrows, and other map elements

Geographic Information Systems are put to many uses, but providing the means to collect, manage, and analyze data to produce information for better decision making is the common goal and the strength of each GIS. This book is a practical guide to understanding and using a particular Geographic Information System called ArcGIS. Using this book, you can learn what a GIS is, what it does, and how to apply its capabilities to solve real-world problems.

A history of GIS

Geographic Information Systems have grown from a long history of cartography begun in the lost mists of time by early tribesmen who made sketches on hides or formed crude models of clay as aids to hunting for food or making war. Ptolemy, an astronomer and geographer from the second century B.C., created one of the earliest known atlases, a collection of world, regional, and local maps and advice on how to draw them, which remained essentially unknown to Europeans until the 15th century. Translated into Latin, it became the core of Western geography, influencing cartographic giants such as Gerhard Mercator, who published his famous world map in 1569. The 17th and 18th centuries saw many important developments in cartography, including the measurement of a degree of longitude by Jean Picard in 1669, the discovery that the earth flattens toward the poles, and the adoption of the Prime Meridian that passes through Greenwich, England. In 1859, French photographer and balloonist Gaspard Felix Tournachon founded the art of remote sensing by carrying large-format cameras into the sky. In an oft-cited early example of spatial analysis, Dr. John Snow mapped cholera deaths in central London in September 1854 and was able to locate the source of the outbreak—a contaminated well. However, until the 20th century, cartography remained an art and a science carried out by laborious calculation and hand drawing. In 1950, Jacqueline Tyrwhitt made the first explicit reference to map overlay techniques in an English textbook on town and country planning, and Ian McHarg was one of the early implementers of the technique for highway planning.

As with many other endeavors, the development of computers inspired cartographers to see what these new machines might do. The early systems developed by these groups, crude and slow by today's standards, nevertheless laid the groundwork for modern Geographic Information Systems. Dr. Roger Tomlinson, head of an Ottawa group of consulting cartographers, has been called the "Father of GIS" for his promotion of the idea to use computers for mapping and for his vision and effort in developing the Canada Geographic Information System (CGIS) in the mid-1960s. Another pioneering group, the Harvard Laboratory for Computer Graphics and Spatial Analysis, was founded in the mid-1960s by Howard Fisher. He and his colleagues developed a number of early programs between 1966 and 1975, including SYMAP, CALFORM, SYMVU, GRID, POLYVRT, and ODYSSEY. Other notable developers included professors Nystuen, Tobler, Bunge, and Berry from the Department of Geography at Washington University during 1958–1961. In 1970, the US Bureau of the Census produced its first geocoded census and developed the early DIME data format based on the CGIS and POLYVRT data representations. DIME files were widely distributed and were later refined into the TIGER format. These efforts had a pronounced effect on the development of data models for storing and distributing geographic information.

In 1969, Laura and Jack Dangermond founded the Environmental Systems Research Institute (ESRI), which pioneered the powerful idea of linking spatial representation of features with attributes in a table, a core idea that revolutionized the industry and launched the development of Arc/Info, a program whose descendants have captured about 90% of today's GIS market. Other vendors are still active in developing GIS systems, which include packages MAPINFO, MGA from Intergraph, IDRISI from Clark University, and the open-source program GRASS.

What can a GIS do?

A GIS works with many different applications: land use planning, environmental management, sociological analysis, business marketing, and more. Any endeavor that uses spatial data can benefit from a GIS. For example, researchers at the US Department of Agriculture Rocky Mountain Research Station in Rapid City conducted a study of elk habitat in the Black Hills of

South Dakota and Wyoming by placing radio transmitter collars on about 70 elk bulls and cows (Fig. I.1c). Using the collars and a handheld antenna, they tracked the animals and obtained their locations. Several thousand locations were collected (Fig. I.1a), allowing the scientists to study the characteristics of the habitat where elk spend time.

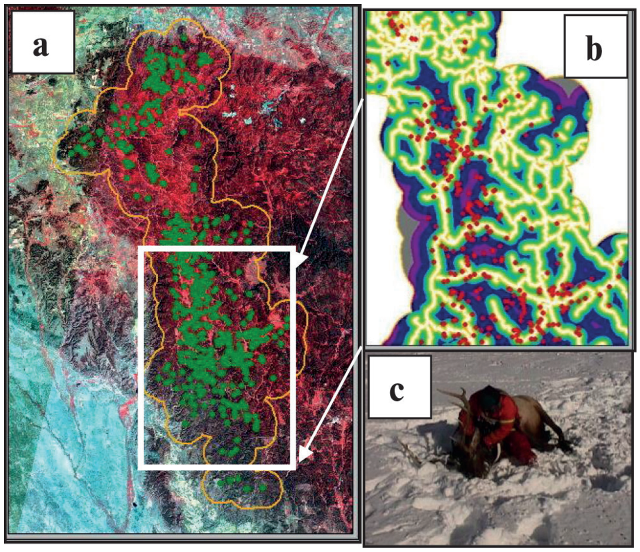

Fig. I.1. Analyzing elk habitat use: (a) elk locations and study area; (b) locations on a map of distance to nearest road; (c) collaring an elk
Source: Courtesy of Mark Rumblße

The elk locations were entered into a GIS system for record keeping and analysis. Each location became a point with attached information, including the animal ID number and the date and time of the sighting. Information about vegetation, slope, aspect, elevation, water availability, and other site factors were derived by overlaying the points on other data layers, allowing the biologists to compare the characteristics of sites utilized by the elk. Figure I.1b shows a map of distances to major roads in the central part of the study area. The elk locations clustered in the darker roadless areas, and statistical analysis demonstrated this observation empirically.

There are many applications of GIS in almost every human endeavor, including business, defense and intelligence, engineering and construction, government, health and human services, conservation, natural resources, public safety, education, transportation, utilities, and communication. In August 2016, the Industries section of the ESRI web site at www.esri.com listed 42 different application areas in these categories, each one with examples, maps, and case studies. Instead of reading through a list here, go to the site and see the latest applications.

New trends and directions in GIS

The GIS industry has grown exponentially since its inception. Starting with the mainframe and then the desktop computer, GIS began as a relatively private endeavor focused on small clusters of specialized workers who spent years developing expertise with the software and data. Since then, the development of the Internet and the rapidly advancing field of computer hardware have been driving some significant changes in the industry.

Proliferation of options for data sharing

Instead of storing data sets locally on individual computers or intra-organization network drives, more people are serving large volumes of data over the Internet to remote locations within an organization, across organizations, and to the general public. In the past, large collections of data were hosted by various organizations through clearinghouses sponsored by the National Spatial Data Infrastructure (NSDI) organization. The data usually existed as GIS data files in various formats and required significant expertise and the right software to download and use. Today, *GIS Servers* are designed to bring GIS data to the general public within a few clicks. Another class of data providers that give wide access to spatial data, although not specifically GIS applications, include web sites such as Google Earth, MapQuest, and Microsoft Virtual Earth.

Like many other computer industries, GIS is heading for the clouds. A cloud is a gigantic array of large computers that customers rent pieces of by the hour, instead of purchasing their own physical hardware. ArcGIS Online is a cloud-based platform for users to collaborate and share GIS data with one another, making it suddenly very easy to share data with a colleague, or with the world, even for those with no particular GIS expertise.

Proliferation of options for working with GIS data

In the early days, people who wanted to do GIS had to purchase a large, expensive program and learn to use it. Now, a wide variety of scaled applications permit different levels of use for different levels of need. Not every user must have the full program. There are map servers for people who just need to view and print maps, free download software for viewing interactive map publications, and scaled-down versions of the full program with fewer options.

Many organizations are turning to Server GIS as a less expensive alternative to purchasing large numbers of GIS licenses. Many workers need GIS, but they only use a small subset of GIS functions on a daily basis. A Server GIS can provide both data and a customizable set of viewing and analysis functions to users without a GIS license. All they need is a web browser. Because of more simple and low-cost ways of accessing GIS data and functions, the user base has expanded dramatically.

Expansion of GIS into wireless technology

More people are collecting and sharing data using handheld wireless devices, such as handheld computers, smartphones, and global positioning system (GPS) units. These units can now access Internet data and map servers directly so that users in the field can download background data layers, collect new data, and transmit them back to the large servers. Cell phone technology is advancing rapidly with new geolocation options, web access, and geo-applications arriving daily.

Emphasis on open-source solutions

Instead of relying on proprietary, specialized software, more GIS functions are now implemented within open-source software and hardware. GIS data are now more often stored using engines from commercial database platforms and utilize the same development environments as the rest of the computer industry. This trend makes it easier to have the GIS communicate with other programs and computers and enhances interoperability between systems and parts of systems.

Customization

With emphasis on open-source solutions, new opportunities have developed in creating customized applications based on a fundamental set of GIS tools, such as a hydrology tool or a wildlife management tool. Smartphone and tablet applications programming is burgeoning. These custom applications gather the commonly used functions of GIS into a smaller interface, introduce new knowledge, and formalize best practices into an easy-to-use interface. Customization requires a high level of expertise in object-oriented computer programming.

Enterprise GIS

Enterprise GIS integrates a server with multiple ways to access the same data, including traditional GIS software programs, web browser applications, and wireless mobile devices. The goal is to meet the data needs of many different levels of users and to provide access to nontraditional users of GIS. The Enterprise GIS is the culmination of the other trends and capabilities already mentioned. The costs and challenges in developing and maintaining an Enterprise GIS are significant, but the rewards and cost savings can also be substantial.

What do GIS professionals do?

It's getting so easy to create a map these days that one may wonder why one should bother to learn GIS. However, the easy solutions are based on the work of experts who provide the data and the software systems to handle them. It may not be that hard to learn to use a smartphone, but you still need the engineers and software developers to build the phones and the infrastructure to make them work. GIS is much the same. These days, GIS professionals play a variety of roles. A few broad categories can be defined.

Primary data providers create the base data that form the backbone of many GIS installations. Surveyors and land-planning professionals contribute precise measurement of boundaries. Transportation agencies develop the street data used by your smartphone to give directions, or even support games like Pokemon Go. Photogrammetrists develop elevation and other data from aerial photography or the newer laser altimetry (LIDAR) systems. Remote sensing professionals extract all kinds of human-made and natural information from a variety of satellite and airborne measurement systems. Experts in global positioning systems (GPS), which provide base data, are also important.

Applications GIS usually involves professionals trained in other fields, such as geography, hydrology, land use planning, business, and utilities, who utilize GIS as part of their work. Specialists in mathematics and statistics develop new ways to analyze and interpret spatial data. For these professionals, GIS is an added skill and a tool to make their work more efficient, productive, and valuable.

Development GIS involves skilled software and hardware engineers who build and maintain the GIS software itself, as well as the hardware components upon which it relies—not only computers and hard drives and plotters but also GPS units, wireless devices, scanners, digitizers, and other systems that GIS could not function without. This group also includes an important class of GIS developers who create customized applications from the basic building blocks of existing GIS software.

Distributed database GIS involves computer science professionals with a background in networking, Internet protocols, and/or database management systems. These specialists set up and maintain the complex server and network systems that allow data services, Server GIS, and Enterprise GIS to operate.

GIS project management

A GIS project may be a small effort spanning a couple of days by a single person, or it can be an ongoing concern of a large organization with hundreds of people participating. Large or small, however, projects often follow the generalized model shown in Figure I.2, and most new users learn GIS through a project approach. A project usually begins with an assessment of needs. What specific issues must be studied? What kind of information is needed to support decision making? What functions must the GIS perform? How long will the project last? Who will be using the data? What funding is available for start-up and long-term support?

Without a realistic idea of what the system must accomplish, it is impossible to design it efficiently. Users may find that some critical data are absent or that resources have been wasted acquiring data that no one ever uses. In a short-term project the needs are generally clear-cut. A long-term organizational system will find that its needs evolve over time, requiring periodic reassessment. A well-designed system will adapt easily to future modification. The creator of a haphazard system may be constantly redoing previous work when changes arise.

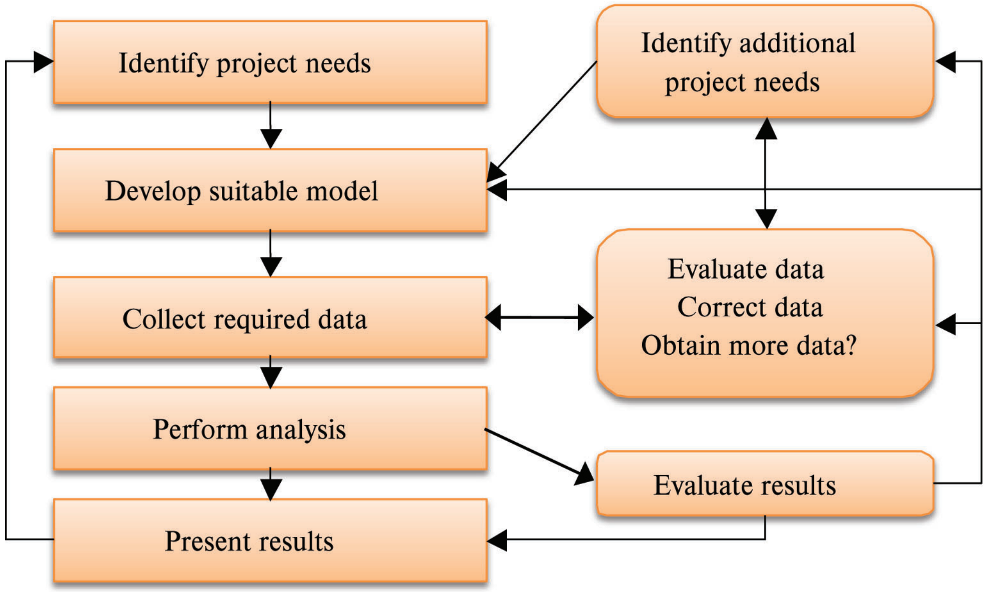

Fig. I.2. Generalized flow diagram representing steps in a GIS project

In studies seeking specific answers to scientific or managerial questions, a methodology or **model** must be chosen. Models convert the raw data of the project into useful information using a well-defined series of steps and assumptions. Creating a landslide hazards map provides a simple example. One might define a model such that, if an area has a steep slope and consists of a shale rock unit, then it should be rated as hazardous. The raw data layers of geology and slope can be used to create the hazard map. A more complex model might also take into account the dip (bedding angle) of the shale units. Models can be very simple, as in this example, or more complex with many different inputs and calculations.

Once needs are known and the appropriate models have been designed, data collection can begin. GIS data are stored as layers, with each layer representing one type of information, such as roads or soil types. The needs dictate which data layers are required and how accurate they must be. A source for each data layer must be found. In some cases data can be obtained free from other organizations. General base layers, such as elevation, roads, streams, political boundaries, and demographics, are freely available from government sources (although the accuracy and level of detail are not always what one might wish). More specific data must often be developed in-house. For example, a utility company would need to develop its own layers showing electric lines and substations—no one else would be likely to have these data.

The spatial detail and accuracy of the data must be evaluated to ensure that they are able to meet the needs of the project. For example, an engineering firm creating the site plan for a shopping mall could download elevation contours of the site for free. However, standard 10-foot contours cannot provide the detailed surface information needed by the engineers. Instead, the firm might contract with a surveying firm to measure contours at half-foot intervals.

After the data are assembled, the analysis can begin. During the analysis phase, it is not unusual to encounter problems that might require making changes to the model and/or data. Thus, the steps of model development, data collection, and analysis often become iterative, as experience gained is used to refine the process. The final result must be checked carefully against reality in order to recognize any shortcomings and to provide guidelines for improving future work.

Finally, no project is complete until the results have been communicated, whether shown informally to a supervisor, published in a scientific journal, or presented during a heated public meeting. Presentations may include maps, reports, slides, or other media.

Learning more about GIS

As you work your way through this text, you will be amazed at all the things that a GIS can do. At times, the abundance of tasks and the flexibility of options may be overwhelming. Even so, this book gives only a bare introduction to what is possible and covers a small portion of what a GIS can do. Moreover, the industry evolves rapidly. Completing the lessons here is only the first step; you will find that you need to seek new information and training constantly as you develop your skills. How can you do this?

- ***Read the Help.*** Maybe you can figure out your cell phone without the manual, but if you ignore the Help files you are turning your back on a wealth of information. They don't just have instructions for doing things but also discussions, diagrams, references, and other ways to help you understand the concepts behind GIS as well as its implementation.
- ***Use online courses.*** ESRI has dozens of online courses and seminars to help you learn. If you have a licensed product, you have access to all of ESRI's online training for free. Talk to your GIS instructor about how to get access to these courses.
- ***Build your GIS library.*** GIS integrates many disciplines, including geography, surveying, cartography, statistics, computer science, spatial statistics, and so on. The more you know of these disciplines, the more you will understand, not just the *How* of doing things but also the *Why*.
- ***Join a professional organization.*** Many professional societies cater to GIS and remote sensing. They have newsletters and journals, conferences, and lots of professionals who can help answer your questions and share their experiences.
- ***Join an online forum.*** You can join an organization called GeoNet, supported by ESRI, that connects you with other GIS users. You can submit questions, look up common software problems, follow groups with similar interests, and communicate with the worldwide network of GIS professionals.
- ***Join ArcGIS Online.*** Not only is it easy and fun to create maps and share them, but you can also search for courses, documents, slideshows, videos, and other GIS-related materials. You can create a public account for free. If your university has a site license, you may also be given a subscription account that offers premium data content, the ability to publish data, and other benefits.

Chapter 1. GIS Data

Objectives

- Understanding how real-world features are represented by GIS data
- Knowing the differences between the raster and vector data models
- Getting familiar with the basic elements of data quality and metadata
- Learning the different types of GIS files used by ArcGIS
- Using ArcMap to view GIS data
- Learning about map documents, layers, and data frames

Mastering the Concepts

GIS Concepts

Representing real-world objects on maps

To work with maps on a computer requires developing methods to store different types of map data and the information associated with them. Map data fall into two categories: **discrete** and **continuous. Discrete** data are objects in the real world with specific locations or boundaries, such as cities, roads, or soils units. **Continuous** data represent a quantity that is measured and recorded everywhere over a surface, such as temperature or elevation.

Many different data formats have been invented to encode data for use with GIS programs; however, most follow one of two basic approaches: the **vector** model, which is designed to store discrete data, or the **raster** model, which is designed to store continuous data. In either approach, the critical task includes representing the information at a point, or over a region in space, using x and y coordinate values (and sometimes z for height). The x and y coordinates are the spatial data. The information being represented, such as a soil type or a chemical analysis of a well, is called the attribute data. Raster and vector data models both store spatial and attribute data, but they do it in different ways.

Both data systems are **georeferenced,** meaning that the information is tied to a specific location on the earth's surface using x-y coordinates defined in a standard way: a **coordinate system.** One can choose from a variety of coordinate systems, as we will see in Chapter 3. As long as the coordinate systems match, we can display any two spatial data sets together, and they will appear in the correct spatial relationship to each other.

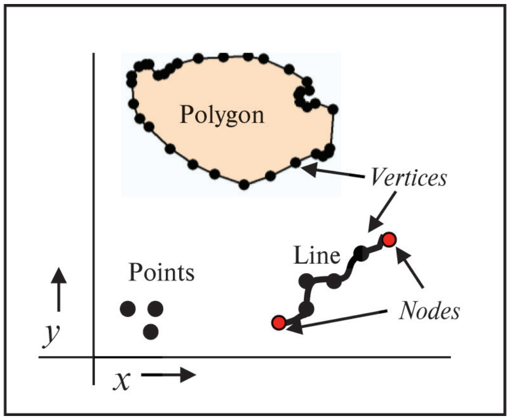

Fig. 1.1. The vector data model uses a series of x-y locations to represent points, lines, and polygon areas.

The vector model

Vector data use a series of x-y locations to store information (Fig. 1.1). Three basic vector objects exist: points, lines, and polygons. These objects are called **features. Point** features are used to