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Keith C. Clarke
Santa Barbara

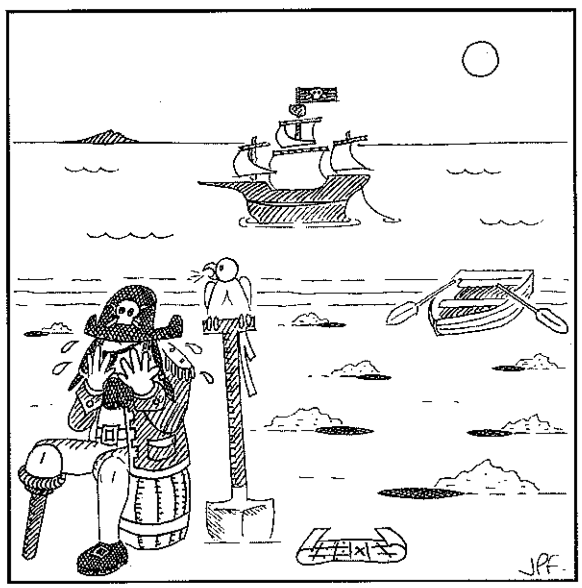
CHAPTER 1

What Is a GIS?

What in the world is a "GIS"?

—Item on the Internet's `comp.infosystems.gis` *FAQ list (FAQ = frequently asked question)*

GISs are simultaneously the telescope, the microscope, the computer, and the Xerox machine of regional analysis and synthesis of spatial data.
—(Ron Abler, 1988)



SQUAWK! "Who needs a GIS?"
SQUAWK! "Who needs a GIS?"

1.1 GETTING STARTED

If you are getting started with geographic information systems (GISs), or perhaps are curious to know what a GIS is and what it can do for you—then this book is for you. Whatever your field of interest, the chances are strong that you will at least come across and probably use a GIS in some way in the years ahead. So getting started now is a good idea! Perhaps you have already checked into some of the sources of information about GIS covered in this chapter. If you have, you may have noticed that there are already a great many GIS textbooks. Why, you may ask, do I need another? What is different about *this* GIS book?

Getting Started with Geographic Information Systems is intended to supplement the many new GIS books, not by updating or adding to them, but by *gently easing new GIS users into their community of understanding* without that long, slow, expensive, and sometimes painful climb up the GIS learning curve. As your first book in GIS, this one will set the foundation for a more breadth-first tour through the discipline than what the more advanced books can offer. By keeping the text up to date, the author and editors are working hard to ensure that your first GIS experience is timely, pleasant, and constructive.

First, we get started with GIS definitions, outline the development of the field, and map out some of the sources of information that can teach you more about GIS. It should be clear at the outset that GIS is not a new "killer app," namely a "must-have" innovative and essential computer application like a spreadsheet, a word processor, or a database manager. GIS is partly a killer app, but the upward shift in capability that its users receive is not due to computer software alone. Instead, GIS has built on the collective knowledge of the academic fields of geography and cartography, with some geodesy, database theory, and mathematics thrown in for good measure. As Ron Abler's definition shows, GIS is not just one but *many* simultaneous technological revolutions. *Getting Started with Geographic Information Systems* introduces a distilled version of the theory and content from the fields of these technologies—the minimum necessary to get you started—and then offers some signposts pointing toward where the revolutions will lead next. If you choose to go further, there are plenty of paths forward.

Using GIS requires you to think like a geographic information scientist. *Geographic information science* is a new field, born by merging skills and theory across many different disciplines, and it has now reached maturity after years of development. Like all new fields, geographic information science requires some mental readjustment. The purpose of this book is to gently guide you, the reader, through this readjustment. Fortunately, because you are reading this book, the chances are that you are already used to thinking graphically, mapping out information, and building analytical solutions around these maps and graphics. If not, I hope that this text will serve both to get you started and to unleash a part of the brain you may never have used before—the spatial part—that holds real power as a new way of problem solving.

1.2 SOME DEFINITIONS OF GIS

Good science starts with clear definitions. In the case of geographic information systems, however, definitions have sometimes been as clear as mud. As a result, different definitions have evolved over the years as they were needed. It is no surprise, then, that "geographic information system" can be defined in many different ways. Which definition you choose depends on what you seek. Common to all the definitions is that one type of data, *spatial data*, is unique because it can be linked to a geographic map (Figure 1.1).

Spatial means "related to the space around us, in which we live and function." Our own definition of GIS can start with a simple description of the three parts of a GIS, which are (1) the database, (2) the spatial or map information, and (3) some way to link the two. Necessary parts are a computer, some software, and people to use the system. We also need an underlying problem or task for which the GIS will be used, such as choosing a site for a nature preserve, routing an ambulance to a house, or maintaining a set of data that citizens of a town can use to become informed. Then, of course, we need both understanding and experience, both of the system and of the problem. As you will quickly learn, the last two items are the hardest to come by.

1.2.1 A GIS Is a Toolbox

A GIS can be seen as a set of tools for analyzing spatial data. These are, of course, computer tools, and a GIS can then be thought of as a software package containing the elements necessary for working with spatial data. If we want to write a book, we might visit a computer store and buy a word processing package in a box to install on our computer. Similarly, if we seek to work with spatial data, one definition of a GIS is the software in the box that gives us the geographic capabilities we need.

Peter Burrough, in his pioneering textbook, defined GIS as "**a powerful set of tools for storing and retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes**" (Burrough, 1986, p. 6). The key word in this definition is "powerful." Burrough's definition implies that GIS is a tool for geographic analysis. This is often called the "toolbox definition" of GIS because it stresses a set of tools each designed to solve specific problems.

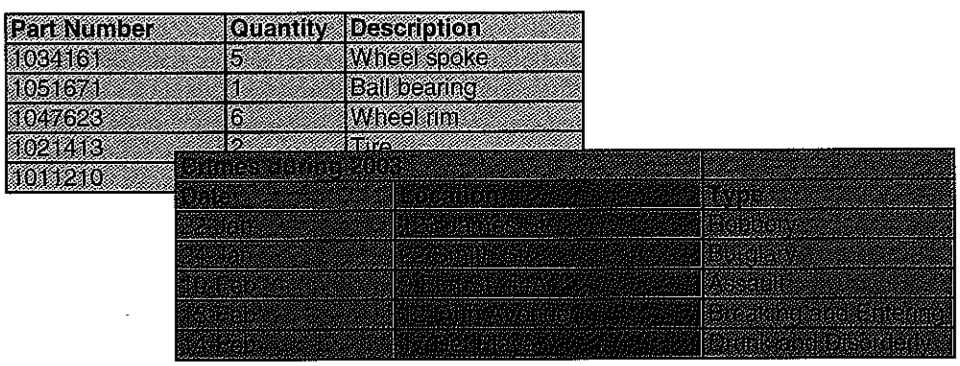


FIGURE 1.1: Two databases. A database contains columns (attributes) and rows (records). The bicycle parts list on the left is not spatial. The parts could be located anywhere. The list of crimes on the right is spatial because one of the attributes, the street address, locates the crimes on a map. This list could be used in a GIS.

If a GIS is a toolbox, a logical question is, What types of tools does the box contain? Several authors have tried to define a GIS in terms of what it does, offering a *functional definition* of GIS. Most agree that the functions fall into categories and that the categories are subtasks that are arranged sequentially as data move from the information source to a map and then to the GIS user and decision maker. Another GIS definition, for example, states that GISs are "**automated systems for the capture, storage, retrieval, analysis, and display of spatial data**" (Clarke, 1995, p. 13). This has been called a "process definition" because we start with the tasks closest to the collection of data and end with tasks that analyze and interpret the information. This book's chapters are structured around this sequence of functions, and each will be discussed in detail as the book progresses.

1.2.2 A GIS Is an Information System

Jack Estes and Jeffrey Star defined a GIS as "**an information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data**" (Star and Estes, 1990, p. 2).

This definition stresses that a GIS is a system for delivering answers to questions or queries, what might be called an *information system* sort of definition. This means that a GIS collects data, sifts and sorts them, and selects and rebuilds them to find precisely the right piece of information to answer a specific question. The reference to geographic coordinates is an important one, because the coordinates are literally how we are able to link data with the map. This theme is examined in detail in Chapter 2.

Another information system definition of a GIS is one that has stood the test of time remarkably well. As such, this definition is worth considerable thought. In 1979, during the infancy of the technology, Ken Dueker defined a GIS as "**a special case of information systems where the database consists of observations on spatially distributed features, activities or events, which are definable in space as points, lines, or areas. A geographic information system manipulates data about these points, lines, and areas to retrieve data for ad hoc queries and analyses**" (Dueker, 1979, p. 106).

The phrase "special case of information systems" implies that GIS has a heritage in information systems technology, which it indeed does. GIS did not invent database management, and there exists in computer science a 40-year tradition in this field all the way from the earliest spreadsheet programs, through relational database management, to the object-oriented database management of today. Information systems are used extensively in library science, in business, and around the Internet.

In Dueker's definition of GIS, the database itself consists of a set of observations, which implies a scientific approach to measurement. Scientists take measurements and record those measurements in some kind of system to help them analyze the data. The observations are *spatially distributed*; that is, they occur over space at different times and at different locations at the same time.

The observations are those of *features*, *activities*, and *events*. A *feature* is a term from cartography meaning an item to be placed on a map. *Point features*, such as an elevation bench mark (Figure 1.2), have only a location. *Line features* have several locations strung out along the line in sequence like a bead necklace, an example being

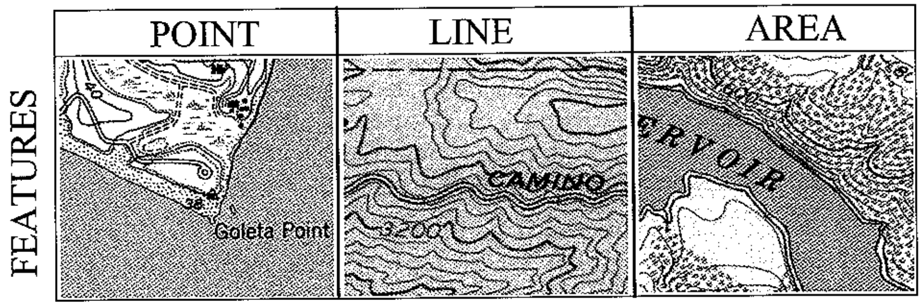


FIGURE 1.2: The Feature Model: Examples of a point feature (38 foot elevation bench mark), a line feature (road, contours), and area features (reservoir, vegetation).

a road or a stream. *Area features* consist of one or more lines that form a loop, such as the shoreline of a reservoir or lake, or the edge of a patch of vegetation. Traditionally, the source of geographic information is the map, and the information on a map consists of a set of graphic symbols, such as colors, lines, patterns, and shades.

"Activities" implies a link to the social sciences. Human activities create geographic patterns and distributions. They lead to the population map, census map, distribution of disease incidences, location of infrastructure, and so on—all related to how people live their daily lives. The "event" part of GIS implies that geographic data fall not only into space but also into time. Time gives us a fourth dimension and becomes a part of the data because events happen in time and features exist over a duration. The reservoir in Figure 1.2, for example, was created by damming a stream and so was not shown on a map made 100 years ago.

Dueker's GIS definition assumes that events also have expressions as points, lines, or areas in space and on the map. An example of a point event is the location of a traffic accident. A line activity could be the flow of electricity along a segment of a power cable. An area event could be the freezing of a body of water, such as the Central Park reservoir in New York City. The information element becomes useful to the GIS user because it exists, it has data associated with it, and it has cartographic reality as a feature on a map.

We use the information mapped in the GIS for doing exactly what an information system should do: solve problems, do queries, come up with the answer, or try out a possible solution. So we manipulate the data, not by hand, but digitally. We manipulate data about events or activities by using the digital map features that represent them as "handles." In other words, *the points, lines, and areas in this map database are used to manage the data*. Another key part of Dueker's GIS definition is that the queries must be ad hoc or context-specific queries. We don't have to know in advance when building a GIS exactly what we want to use it for. This means that GIS is a generic problem-solving tool; it is not something built just for that project or to get this week's assignment done. The value of GIS comes from its ability to apply general geographic methods to specific geographic regions.

Finally, in Dueker's definition a GIS can also do analysis. Usually, the purpose of having data in GIS form is so that an analyst can extract what is necessary to make predictions and explanations about geographic phenomena. A focus on GIS technology ignores the fact that the ultimate purpose of the system is to solve problems. Geographic information science goes beyond description, to include analysis, modeling, and prediction. The information systems definition, then, leads back to the role of a GIS as a problem solver. It begs the question: Is this just one more scientific method, or is this a new scientific approach?

1.2.3 GIS Is an Approach to Science

As a tool or as an information system, GIS technology has changed the entire approach to spatial data analysis. GIS has already been compared to not one but several simultaneous revolutionary changes in the way that data can be managed. The convergence of GIS with allied technologies, those of surveying, remote sensing, air photography, the global positioning system (GPS), and mobile computing and communications has fed a spectacular growth of these technologies.

As a result, the way of doing business—the standard operating procedure of geographic and spatial information handling—has rapidly restructured itself. First, the technology of GIS has become much simpler, more distributed, cheaper, and has crossed the boundary into disciplines such as anthropology, epidemiology, facilities management, forestry, geology, and business. Second, this mutation has led to a culling of the body of knowledge that constitutes geography so that it is suitable for use in these parallel fields as a new approach to science. Goodchild called this "geographical information science" (Goodchild, 1992). In the United States the preferred term is *geographic information science.*

Goodchild defined geographic information science as **"the generic issues that surround the use of GIS technology, impede its successful implementation, or emerge from an understanding of its potential capabilities"** (Goodchild, 1992). He also noted that this involved both research *on* GIS and research *with* GIS. Supporting the science are the uniqueness of geographic data, a distinct set of pertinent research questions that can only be asked geographically, the commonality of interest of GIS meetings, and a supply of books and journals. On the other hand, Goodchild noted that the level of interest depends on innovation, that it is hard to sustain a multidisciplinary (rather than interdisciplinary) science, and that at the core of the science, in geography, a social science tradition has to some extent an antipathy toward technological approaches.

This book is an effort to distill from the discipline of geography exactly those components that are derived from the areas of research outlined by Goodchild. As such, this book adopts Goodchild's approach. The chapters that compress the principles of cartography are Chapters 2 and 7; analytical cartography's contributions fall into Chapters 3–5; and spatial analysis is discussed in Chapter 6. Added to these are doses of general geography, database management, and applied GIS. This knowledge base constitutes the new and strengthening field of geographic information science.

1.2.4 GIS Is a Multibillion-Dollar Business

Groups monitoring the GIS industry estimate the total value of the hardware, software, and services conducted by the private, governmental, educational, and other sectors that handle spatial data to be billions of dollars a year. Furthermore, for the last half decade of the 1990s, and into the current decade, the industry has seen double-digit annual growth. Anyone who attends a national or international conference in the field can feel

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Plays a Role in Society

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environment, it is very important to have a "champion," someone who

an overwhelming sense of rapid growth, sophistication, and the sheer magnitude of the transformation that GIS has led.

Largely responsible for this situation were the massive cost reductions in technology dating from about 1982, when computers moved out from behind glass windows as tended by people in white coats and onto the desktop. This decline in cost, aided by the success of the workstation as a tool in engineering settings, has led to a rapid increase in what is usually called the "installed base" of GIS. Just about every major academic institution in the United States and in many other countries now teaches at least one class in GIS. Most local, state, and federal government agencies use GIS, as do businesses, planners, architects, foresters, geologists, archeologists, and so on. This growth in pure numbers, added to the increase in sophistication of the systems, is what has led to the big business aspect of GIS.

However, other steps have been critical to the booming (and blooming) of GIS. First, the industry was founded on vast amounts of inexpensive federal government data, mostly data of the U.S. Census Bureau and the U.S. Geological Survey. Second, the community has been a successful advocate of the field and has rapidly developed an infrastructure for self-support, user groups, network conference groups, and so on. Third, the addition of graphical user interfaces and the addition of extremely useful features such as help screens and automatic installation routines have played an essential role. Fourth, GIS has merged successfully with parallel technologies and has benefited from the resultant multiplier effect.

The growth of GIS has been a marketing phenomenon of amazing breadth and depth and will remain so for many years to come. Clearly, GIS will continue to integrate its way into our everyday life to such an extent that it will soon be impossible to imagine how we functioned before. The GIS operations could become so transparent to the public that we would not even realize that GIS was there, just as we give no thought to the microprocessor that calculates our change at the cash register. Then again, many would argue that it already has done just this.

1.2.5 A GIS Plays a Role in Society

Many people doing research on GIS have argued that defining GIS narrowly, as a technology, as software, or as a science, ignores the role that GIS plays in changing the way people live and work. Not only has GIS radically changed how we do day-to-day business, but also how we operate within human organizations. Nick Chrisman (1999) has defined GIS as "**organized activity by which people measure and represent geographic phenomena then transform these representations into other forms while interacting with social structures**."

This definition has emerged from an area of GIS research that has examined how GIS fits into society as a whole, including its institutions and organizations, and how GIS can be used in decision making, especially in a public setting such as a town meeting, or on a community group Web site. This latter field is termed PPGIS, for Public Participation GIS.

Few people would doubt that as GIS has become part of the way of doing business within many organizations, such as planning offices or state planning agencies, the result has been a shifting in the work assignments, job descriptions, responsibilities, and even the power relationships of the organization. For example, when GIS is first introduced into a work environment, it is very important to have a "champion," someone who is a GIS advocate from within the group. Many in the study of GIS have focused on describing and analyzing these impacts rather than looking technically at GIS, or at GIS in its application. So far, the field has generated a history of the discipline (Foresman, 1997) and an increasingly popular set of meetings and conferences. Several books have stimulated interest in this approach, including *Ground Truth* (Pickles, 1995), which introduced the somewhat more humanistic and social science dimension to GIS research work.

Nick Chrisman's definition of GIS includes all of the social process of GIS functions. For example, a GIS may be used to capture data about land holdings as ownership parcels. However, the use and purpose of the data and their dissemination will vary according to the philosophy and traditions of the community in which the data are being used. In a growth-oriented community, for example, a GIS might be seen as a mechanism for expediting building permits and increasing land sales. In a more conservation-oriented community, a GIS might be seen and used as a vehicle for raising public awareness about environmental issues, supporting community planning, or enforcing pollution controls. Although essentially the same GIS software, hardware, and data may be in place in the two settings, the staff, their work assignments, and the degree of administrative control might be very different. It is the human factors involved that determine much about the GIS, rather than the technical capabilities.

Another component that Chrisman's definition recognizes is the importance of a basis in measurement. In the abstract sense, a GIS supports measurements about the land with many different levels of accuracy and reliability. In most cases, the GIS is based on the "best available data," but virtually always some of the data are incomplete, outdated, or missing. How GIS users come to terms with this problem is often as large a factor in the GIS's capabilities and effective use as are the software, hardware, and processes involved. As we state later, a GIS, like a map, is often a set of errors that have been agreed on. This definition notes that not just the errors and the system supporting them define GIS, but also those critical agreements about the data that result among the people involved.

1.3 A BRIEF HISTORY OF GIS

Many of the principles of the new geographic information science have been around for quite some time. General-purpose maps date back centuries and usually focused on topography, the lay of the land, and transportation features such as roads and rivers. More recently, in the last century, thematic maps came into use. Thematic maps contain information about a specific subject or a theme, such as surface geology, land use, soils, political units, and data collection areas. Although both types of maps are used in GIS, it is the thematic map that led cartography toward GIS. Some themes on maps are clearly linked. For example, a map of vegetation is closely tied to a map of soils.

It was the field of planning that first began to exploit thematic maps by extracting data from one map to place them on another. As an early example, the geographic extent of the German city of Dusseldorf was mapped at different time periods in this way in 1912, and a set of four maps of Billerica, Massachusetts, were prepared as part of a traffic circulation and land-use plan in the same year (Steinitz et al., 1976). By 1922, these concepts had been refined to the extent that a series of regional maps were prepared for Doncaster, England, which showed general land use and included contours or isolines of traffic accessibility. Similarly, the 1929 "Survey of New York and Its Environs" clearly shows that overlaying maps on top of each other was an integral part of the analysis, in this case of population and land value.

In 1950, the publication of the *Town and Country Planning Textbook* in Britain included a landmark chapter, "Surveys for Planning," by Jacqueline Tyrwhitt (Steinitz et al., 1976). Various data themes, including land elevation, surface geology, hydrology/soil drainage, and farmland, were brought together and combined into a single map of "land characteristics" (Figure 1.3). The author described how the maps were drafted at the same scale, and how map features were duplicated so that the maps could be superimposed precisely, using these features as a guide. Just as many others had "discovered" America, it was Columbus who is remembered because he was the first to write about it (and, incidentally, to draw a map!).

In 1950, the technique of map overlay, now so common in GIS packages, was "invented" by Tyrwhitt, although it is likely that there were earlier precedents. Nevertheless, it is clear that by 1950, maps were regularly being traced onto transparent overlays for use in land analysis and presentation. Twenty years later, Ian McHarg, in his 1969 book *Design with Nature*, described using blacked-out transparent overlays to assist in finding locations in New York's Staten Island that were solutions to multiple siting control factors (Figure 1.4).

As early as 1962, two planners at the Massachusetts Institute of Technology had evolved the map overlay idea to include weighting, by making the overlays different in their importance with respect to each other. The plan involved 26 maps showing the desirability of highways. Maps were ordered in a "procedural tree," and different combinations were made by reordering the map layers photographically.

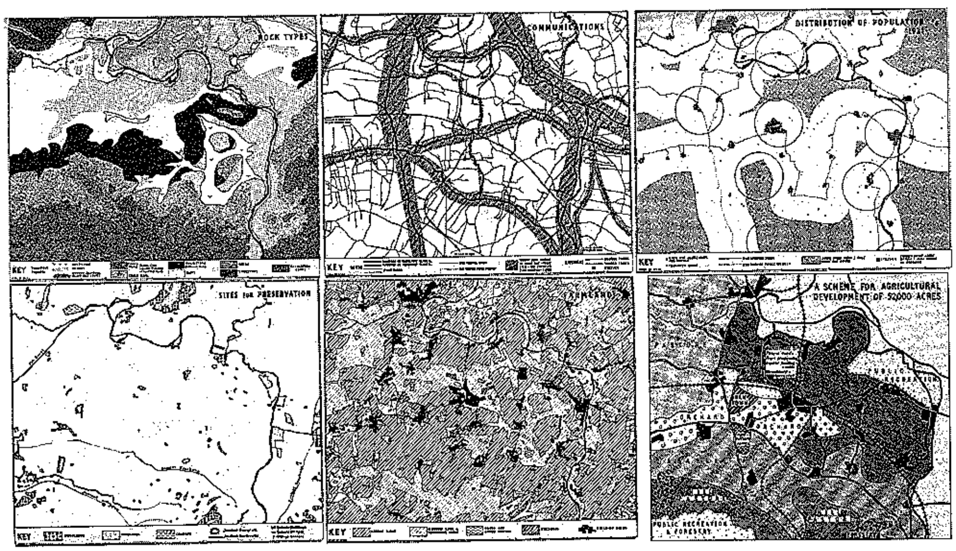


FIGURE 1.3: Map overlay as presented in Town and Country Planning Textbook by Jacqueline Tyrwhitt. Map at lower right is a composite overlay of several others, and is used to plan a community by applying basic map layer overlay principles.

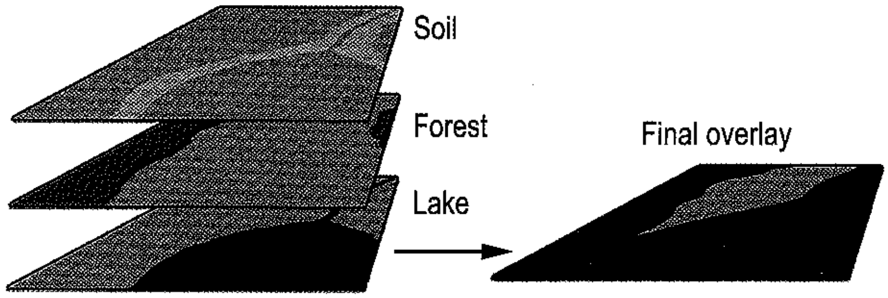


FIGURE 1.4: Map overlay as presented in *Design with Nature* by Ian McHarg. Each transparent layer map "blacked out" areas excluded as unsuitable locations.

During the 1960s, many new types of thematic maps were becoming available in standardized scales, such as topographic and land cover maps from the U.S. Geological Survey and soil maps from the U.S. Department of Agriculture's Soil Conservation Service (now the Natural Resource Conservation Service). It became fairly straightforward to select the right maps, trace off a layer, or photographically build a "separation" for one type of feature on the map, and then to combine the layers mechanically.

The scene was set for the arrival of the computer. In 1959, Waldo Tobler, then a graduate student, published a paper in *Geographical Review* outlining a simple model for applying the computer to cartography (Tobler, 1959). His model, often referred to as a MIMO (map in–map out) system, had three elements: a map input, map "manipulation," and a map output stage. These three simple steps were the distant origins of the geocoding and data capture, data management and analysis, and data display modules now part of every GIS package.

Within just a few years, many people were busy writing computer programs using programming languages such as FORTRAN to draw maps using primitive printers and plotters. The new demands on computing led to the development of the first digitizer by the New Haven group planning the 1960 census and to the development of many other new devices. As new capabilities for mapping came along, the first experiments with entirely new mapping methods, such as animation and automated hill shading, took place. Nevertheless, none of these early systems could be described as a GIS. During the early years, development of computer mapping resulted in less and less dependence on individual computer programs and more and more on *software packages*, sets of linked computer programs that had common formats, structures, and files. When *modular computer programming languages* came along during the 1960s, the process of writing integrated software became easier. Among the early computer mapping packages were SURFACE II, IMGRID, CALFORM, CAM, and SYMAP.

Most of these programs were sets of modules for the analysis and manipulation of data and the production of choropleth (shaded area) and isoline (contour) maps. With these packages it was possible to overlay data sets, reducing the hard work of doing this only with transparencies. Closely related to the mapping software was the development of the first systematic map databases. First came the Central Intelligence Agency's (CIA) World Data Bank, a global map of coastlines, rivers, and national boundaries still in use today, along with the CAM software that projected it onto maps at different scales.

After many prototype systems, the DIME (dual independent map encoding) coding system was devised by the U.S. Census Bureau as an experiment in digital mapping and data handling. The DIME and the resultant files, called geographic base files (GBFs), were a major breakthrough in the history of geographic information representation. The GBF/DIME recognized that attribute information, in this case all the data collected by the census, and the computer maps used in planning the census could be integrated not just for mapping but also to search for geographic patterns and distributions. Some landmark early systems were the Canada Geographic Information System (CGIS) in 1964, the Minnesota Land Management System (MLMIS) in 1969, and the Land Use and Natural Resources Inventory System in New York (LUNR) in 1967. Both MLMIS and LUNR were derivatives of the GRID system that replaced SYMAP at Harvard University.

During the mid and late 1960s a cluster of faculty and students at Harvard University's Laboratory for Computer Graphics and Spatial Analysis made some major theoretical contributions and developed and implemented several new systems. Most influential among these was the GIS program Odyssey. With program modules named for sections of Homer's *The Odyssey*, the team pioneered a set of data structures that came into common use after their publication in 1975 (Peucker and Chrisman, 1975) called the *arc/node* or *vector* data structure. The computer routines that sorted digitized chains and lines and assembled topologically connected polygons, for example, was called the *Whirlpool.* Odyssey was a highly influential arc/node-based GIS and influenced much of the software that followed.

In Chapter 4 we will examine this structure in some detail, but what was different then was that the data structure captured polygon information using a series of nodes; there was a beginning node and an ending node with an arc between them. The arcs could be assembled to construct a polygon because the structure contained information about adjacency and connectivity between features. Many GIS packages, including Arc/Info, have been based on this simple model of geographic features.

In 1974 the International Geographical Union surveyed software in the mapping sciences and found enough GIS software to publish an entire inventory volume entitled *Complete Geographical Information Systems.* While in the early days many different terms were used to describe a GIS, this report began the convergence on the term GIS as a generic name for this new applications and research field. Reporting on the results of the survey, Kurt Brassel noted that "we understand that a mapping system is mainly designed for display purposes, even though it may fulfill some secondary functions that are not graphical. A geographical information system is designed for a broader range of applications, even though mapping functions may represent an important subset of its activities" (Brassel, 1977, p. 71). Both GIS and computer mapping continue to have this significant and constructive overlap in their content.

Development of GIS persisted into the 1980s, with large computers and FORTRAN continuing to dominate. In 1982, IBM introduced its PC, or personal computer, following from the Apple II microcomputer of a few years earlier. The impact of this single advance cannot be understated. Within just a few years, some of the large GIS packages, such as Arc/Info, had made the difficult transition to the microcomputer. Others, such as IDRISI, owe their origin to the low cost and high degree of efficiency that characterized the first generation of PCs. Other packages migrated instead to the new workstation platform that had developed from the minicomputer and networking trend. Again, other packages, such as GRASS, owe their origins to this transition.

The 1980s and early 1990s saw GIS mature as a technology. Many older packages that failed to move to the new languages and platforms died out, to be replaced by newer systems that could exploit the capabilities of the more powerful equipment. Costs of storage fell remarkably, computer power increased many-fold, and the first generation of GUIs or graphical user interfaces, among them X-Windows, Microsoft Windows, and Apple's Macintosh, made the software considerably easier to use, adding features such as menus, online manuals, and context-sensitive help. During the 1980s, the Internet arose out of the collection of early networks, such as Arpanet and NSFNet, that were beginning to link scientists and became a significant new component of computing.

The 1980s also saw the origins of the infrastructure for GIS: the books, journals, conferences, and other resources that are so critical to finding out about GIS. During this era, the National Science Foundation created the National Center for Geographic Information and Analysis (NCGIA), which devised a national college curriculum and developed broad research agendas for academic research on GIS.

The 1990s saw remarkable growth in the GIS world. Several new factors emerged. First, GIS spread far beyond its origins in the mapping science to encompass developments in new fields such as geology, archeology, epidemiology, and criminal justice. Also, the cost of GIS fell markedly after a series of desktop GIS products emerged. The increasing market penetration of personal computers, and the more mobile laptop and portable digital assistants, took GIS into many new work environments. Object-oriented programming approaches made radical improvements in the software engineering that could be applied to GIS software and allowed the portability of programs across many computer platforms.

In addition, GISs became fully integrated with the global positioning system, greatly enhancing the system's data capture capability. High-resolution imagery became common as a reference base for GIS data. Finally, the emergence of the Internet and e-commerce has placed GIS onto the World Wide Web as Web-GIS. Many now talk of a new era of g-commerce or g-trade, based on geographically enabled Web search capability rather than simply map display.

And so we arrive at the present. Although GIS's lineage dates back to the roots of cartography and although thematic cartography and map overlay date from the nineteenth century, what is today known as GIS owes its birth to a cluster of interrelated events and human interactions in the 1960s, and its spectacular growth to the microcomputer, the workstation, and the Internet. It is, indeed, a rather short history and one that is still being written.

1.4 SOURCES OF INFORMATION ON GIS

This section is designed to help you find more information about GIS topics not covered or covered in insufficient depth in this basic book. Historically, GIS has been a somewhat disjoint field from a reader's standpoint, and most of the major books, journals, and online resources date from only the last few years. This is far less an issue today, however, and there are now some excellent sources of GIS information. These fall into groups and are covered here under journals and magazines, books, professional societies, the Internet and the World Wide Web, GIS conferences, and educational organizations and universities.

The amount of information available about GIS is somewhat overwhelming. An excellent place to begin one's search is at a library, or perhaps by connecting to the Internet and using one of the World Wide Web search tools. This is possible even at one's home computer, but slow enough that a visit to the library may be more productive. Some libraries have facilities to connect to network search systems and even specialized staff with training in geographic information.

As in our definition of geographic information science, the information sources on GIS fall into the broad categories of research *with* GIS and research *on* GIS. As a beginner, try restricting your search to basic material rather than going straight to the research frontier. This can come later. A good way to research a topic is to find publications that came out at about the time a new idea was being introduced. In the older papers, articles, or book chapters, the authors had to write for an audience that would be unfamiliar with the language and concepts under discussion. This is the case in several classic papers in the GIS arena. The writing remains today as a good first step toward understanding and an excellent place to get started with GIS.

1.4.1 Journals and Magazines

Today many journals and magazines publish articles and papers on GIS, and a large number occasionally publish a few papers or a special issue. Journals that publish exclusively on GIS include the academic research journals *International Journal of Geographical Information Systems*, *Geographical Systems*, and *Transactions in GIS*, and the news and applications periodicals *Geospatial Solutions, Geoinformatics,* and *GeoWorld.*

Some journals are specialized in their audience. For example, *Business Geographics* catered to the business world until it stopped publishing in June 2001, *GIS Law* to the legal profession, and *GrassClippings* to users of the GRASS GIS package. There are also regional journals, such as *GIS Asia/Pacific* and *GeoEurope*. Many foreign-language journals exist.

Among the scholarly journals that publish academic work about GIS and its uses are the *Annals of the Association of American Geographers*; *Cartographica*; *Cartography and GIS*; *Computer*; *Computers, Environment, and Urban Systems*; *Computers and Geosciences*; *IEEE Transactions on Computer Graphics and Applications*; the *URISA Journal* (Urban and Regional Information Systems Association); and *Photogrammetric Engineering and Remote Sensing.* The latter devotes one issue a year entirely to GIS.

Some journals carry occasional articles, including *Cartographic Perspectives, Cartographica, Journal of Cartography*, *Geocarto International*, *IEEE Geosciences*, the *International Journal of Remote Sensing*, *Landscape Ecology*, *Remote Sensing Review* and *Infoworld.* GIS is also occasionally national news, with articles in leading newspapers and weekly magazines.

1.4.2 Books

Over the last few years, many books have been written that relate to GIS, although not all have been aimed at the new GIS user. The first generation of GIS books was targeted more toward the advanced user or expert in GIS who wished to see where research in a specialty was going. Some early sources of information for those in GIS were the set of collected readings by Marble et al. (1984), Ripple (1987; 1989), and Worrall (1991a).

At one time in most college classrooms, faculty taught the courses in GIS using reproductions of classic journal papers, so books containing collections of readings served an important role. The first comprehensive textbook in GIS appeared in 1986: Peter Burrough's book *Principles of Geographical Information Systems for Land Resources Assessment.* Burrough's text was used almost exclusively until the appearance of several other works in the late 1980s and 1990s, including those by Star and Estes (1990), Tomlin (1990), Laurini and Thompson (1992), Aronoff (1989), Huxhold (1991), Chrisman (1997), DeMers (1997), and the second edition of Burrough's *Principles* (Burrough and McDonnell, 1998). Recent additions include Longley et al. (2001) and Lo (2002).

The textbooks share the fact that they are written primarily for the advanced student in a college classroom. The professional market includes a large number of people in small offices, planning divisions, and so on, who also need information and training. These individuals have been adequately served by the professional book market, from both a tutorial and a reference perspective.

Aimed at particular segments of users, GIS books have covered such disciplines as health (DeLepper et al., 1995), business (Grimshaw, 1994), surveying (Onsrud and Cook, 1990), management (Aronoff, 1989; Obermeyer and Pinto, 1994), defense (Ball and Babbage, 1989), geology (Bonham-Carter, 1994), social theory (Pickles, 1995), archeology (Allen et al., 1990), urban planning (Huxhold, 1991), public health (Cromley and McLafferty, 2002), history (Knowles, 2002), environmental modeling (Clarke et al., 2002), and landscape ecology (Haines-Young et al., 1993).

Strictly from the professional's perspective, several books serve as comprehensive guides to the industry and technology of GIS as a whole, in some cases listing and reviewing the sources covered in this section. Among these are the AGI Source Book (AGI, 1995), Berry (1993), Antenucci (1991), Korte (1994), and Montgomery and Schuch (1993). Others are aimed at training in particular and are specific to one or another of the various GIS software packages on the market, such as ESRI (1995).

Some books look at a particular component of the more advanced end of GIS research, among them the inclusion of time as a data element (Langran, 1992), three-dimensional visualization (Raper, 1989), data accuracy (Goodchild, 1989), data structures (Samet, 1990), and analytical cartography (Clarke, 1995). Finally, one source has tried to conduct a comprehensive overview of the entire field of GIS, including surveys of applied, theoretical, and research frontier contributions. This rather lengthy and expensive set of volumes (Longley et al., 1999), now in its second edition, is recommended as a reader and source of more detailed information for all GIS scholars. Another comprehensive reference source is Bossler's manual (Bossler, 2002).

It is almost impossible to keep up with the GIS literature from a static source such as this book. Searches under "Geographic Information System" using Google (`www.google.com`) yielded 265,000 hits in February of 2000 and 218,000 in June of 2002 (assuming more stringent search rules). Even Amazon.com (`www.amazon.com`) showed 29 items. Two recent projects have attempted separate online bibliographies on GIS, covering books, journals, and proceedings volumes from meetings. These two Web-based projects are the GIS Master Bibliography (Web location `http://liinwww.ira.uka.de/bibliography/Database/GIS/index.html`) and the Spatial Odyssey (`http://wwwsgi.ursus.maine.edu/biblio/`). Clearly, GIS as a "literature" is a moving target.

1.4.3 Professional Societies

The major GIS journals follow the professional societies closely, and many have book distribution lists with member discounts. The professional societies associated with the technology are the *American Congress of Surveying and Mapping*, the *American Society for Photogrammetry and Remote Sensing* (ASPRS), the *Association of American Geographers*, the *Geospatial Information and Technology Association*, and the *Urban and Regional Information Systems Association* (URISA).

The ACSM (American Congress of Surveying and Mapping) has member organizations, each of which has an interest in GIS, including the Cartographic and Geographic Information Society. Journals produced are *Cartography and Geographic Information Systems*, formerly the *American Cartographer*, and *Surveying and Land Information Systems*. The American Society for Photogrammetry and Remote Sensing covers the mapping science fields broadly. Its journal, *Photogrammetric Engineering and Remote Sensing*, is monthly and has taken on a very strong GIS theme over the last few years. Once a year the journal publishes a special issue on GIS. The journal itself publishes GIS articles in an even balance with traditional mapping and remote sensing. The Association of American Geographers (AAG) has a GIS specialty group, which constitutes the largest specialty group within the organization. The association has regular regional and annual national meetings, and the organization supports a newsletter with job listings.

URISA is a large organization aimed primarily at professionals in planning, government, infrastructure, and utilities. The organization holds an annual national conference and hosts many activities, including job listings, it publishes a journal, and it distributes newsletters. Another professional organization is the Geospatial Information and Technology Association. This group hosts an annual national conference, publishes conference proceedings and other publications, issues a newsletter, and provides scholarships and internships for college students to work in GIS firms.

1.4.4 The Internet and the World Wide Web

An extraordinary, indeed overwhelming, amount of information about GIS can be found on the Internet using the World Wide Web (WWW). Everything from newsgroup frequently asked questions (FAQs) to commercial GIS software vendors' Web sites, to entire online and downloadable GIS packages, such as GRASS, is available.

The best way to search is to load a suitable Web browser such as Internet Explorer or Netscape, and then follow your own interest. Although slow, this is possible from a home computer using a modem and an online service such as America Online. The bibliography at the end of this chapter lists some of the places where GIS information resides, but there are many, many more, and even more are added every day. The network news group GIS-L (comp.infosystems.gis) is a long-standing source of technical information on GIS (Figure 1.5). Users post questions to the list, and people answer back. Replies are archived, and when common threads emerge, they are compiled into a FAQ list, sometimes echoed and hosted on sites across the World Wide Web. GIS-L is currently hosted by the URISA professional organization at `http://www.hdm.com/urisa3.htm`. Following discussions on GIS-L is an excellent way to get an introduction to the software and environment of GIS applications.

One very useful GIS online resource is a network-accessible copy of the U.S. Geological Survey's brochure *Geographic Information Systems* (Figure 1.6) and accessible at

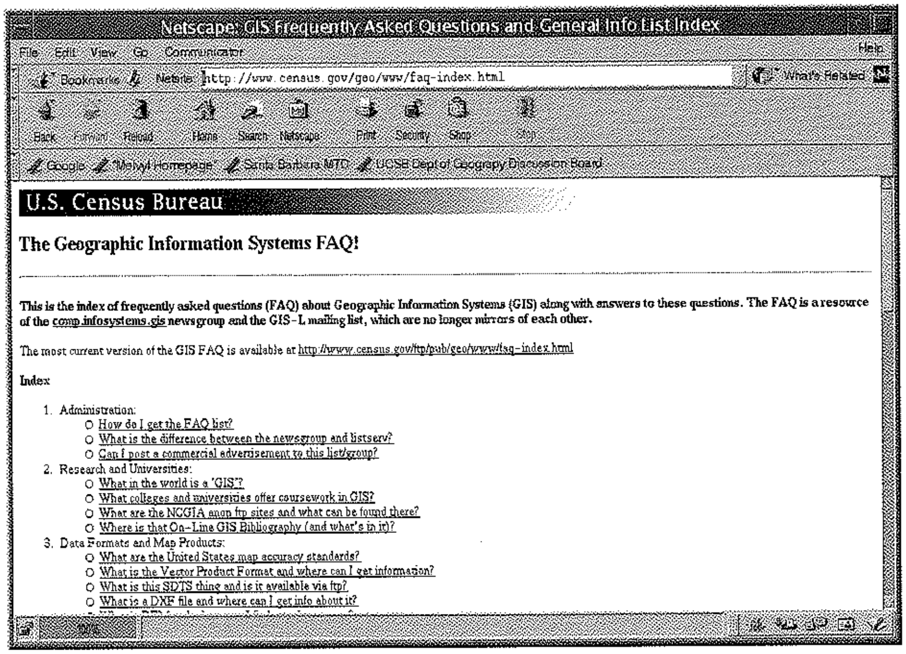


FIGURE 1.5: Web page for GIS-L FAQ index maintained by the U.S. Census Bureau. (See: `http://www.census.gov/geo/www/faq-index.html`.

`http://www.usgs.gov/research/gis/title.html`. This Web document was originally a wall-size poster, also available free, containing all sorts of GIS samples, examples, and definitions.

A recent addition to the Internet GIS information sources are news services that update frequently, some daily, information about GIS. Among these are GIS Monitor `www.gismonitor.com`, Spatial News `www.spatialnews.com`, the GIS Café `www.giscafe.com`, and Geoplace, home of several of the news and information journals (`www.geoplace.com`). Some of these will send you daily updates on the Web site's contents by e-mail.

More information about the GIS data available on the WWW is included in Chapter 3. Newly available are the various data clearinghouses now forming part of the Spatial Data Clearinghouse, an online "library catalog" of available GIS format data available free or at cost. In addition to acting as a library, the WWW also serves as an information source, a software source, a data source, and even as a place to publish results. In Chapter 10, the future role of the WWW and the Internet is discussed from a GIS viewpoint.

1.4.5 Conferences

As a growing and new industry, especially in the early days when there was as yet no major journal where research and applications were published, the various professional conferences for GIS served as "literature." As a result, some of the key papers in GIS technology and theory appear, at least in their early and most readable form, as papers

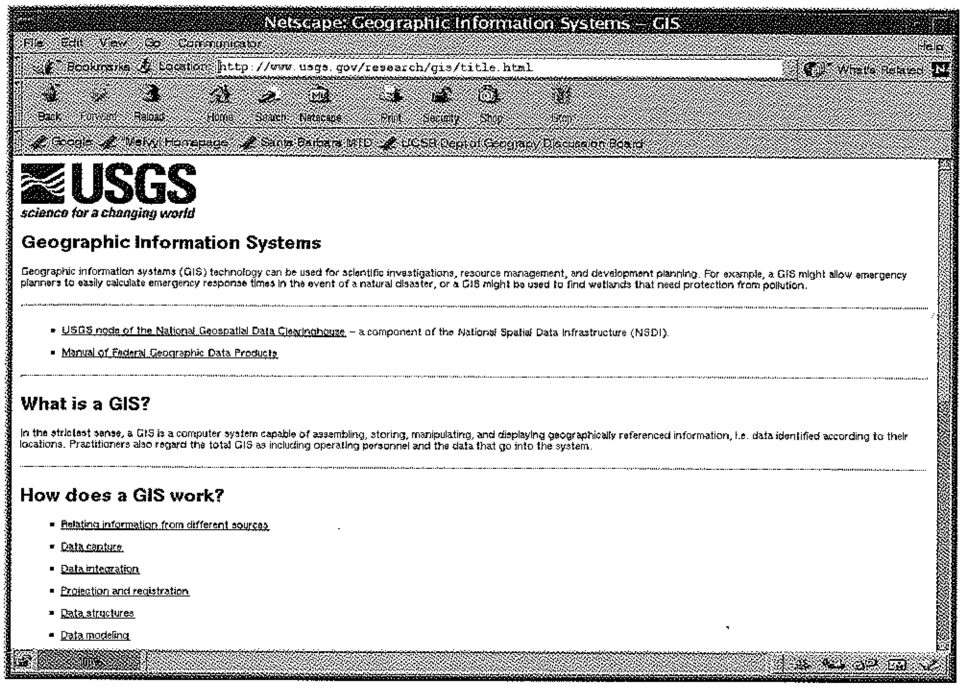


FIGURE 1.6: Entry point on the World Wide Web for the USGS brochure *Geographic Information Systems*, an excellent first glimpse of GIS capabilities. `http://www.usgs.gov/research/gis/title.html`. (Used with permission.)

in conference proceedings. Unfortunately, these papers are often hard to find. In many cases, the professional societies sell back copies of proceedings at a discount.

The earliest conference in GIS was probably the original Harvard Conference on Topological Data Structures. Very soon, the AutoCarto (International Symposium on Automated Cartography) took over as a key place for the publishing of papers. This series now has 12 volumes, with the most recent conference in 1995. During the 1980s, the GIS/LIS conference became a leading focus of GIS activity but was terminated in 1998, having completed its major task. The proceedings remain as a valuable GIS resource.

Other major conferences have been the URISA annual conference, which has more of a GIS application focus; the ACSM/ASPRS technical meetings, with both a research and applications orientation; and the GITA conference, which is the one many municipalities and industrial GIS users attend (Figure 1.7). The biannual spatial data handling conference, held alternately in the United States and internationally, has become a major concentration of people working on GIS research and development. Several states, including New York, Texas, California, and North Carolina, also hold annual meetings. In addition, the various GIS packages or local areas hold their own user group meetings, some of which even approach the professional conferences in size. Largest of them all is the ESRI User Conference, held annually in San Diego, California, with over 10,000 attendees.

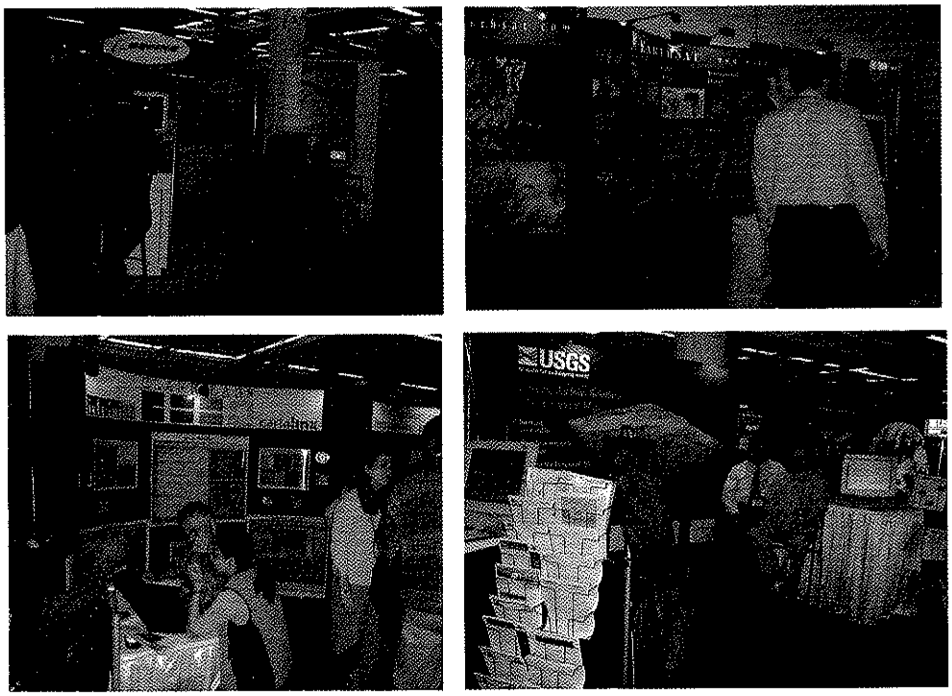
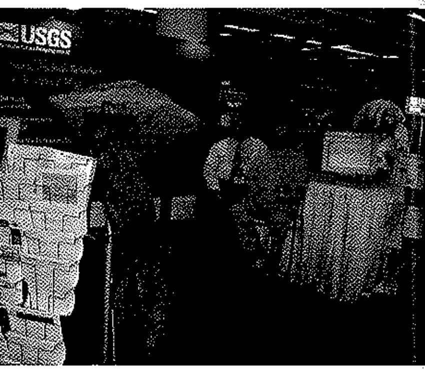


FIGURE 1.7: Selected photographs taken in the exhibits area at the ACSM/ASPRS/FIG conference in Washington, D.C. in April, 2002. (Photographs by the author.)

1.4.6 Educational Organizations and Universities

Many colleges and universities teach classes in GIS, and some offer complete programs with course sequences and certificates. No national body as yet certifies people in GIS, but some vendors offer certification as instructors. Some universities and extension services offer short courses, and most of the major GIS vendors offer short training programs lasting anywhere from a few hours at a national or regional conference to several days or weeks.

Within universities and colleges, GIS classes are taught in many departments. Most are in geography, but many are also in departments and programs in geology, environmental science, forestry, civil engineering, computer and information science, and many others. There is little consensus among those teaching GIS as to what the content for a course in GIS should be, although standardization efforts are under way. Many programs around the country offer just a single class, structured in much the same way as this book. Others use the national GIS curriculum of the National Center for Geographic Information and Analysis (NCGIA) (Figure 1.8). This center is a National Science Foundation–funded program designed to channel GIS research and learning toward an improvement for the discipline of geographic information science. The center, a consortium of three universities, maintains a Web site at `http://www.ncgia.ucsb.edu`. The group has conducted a comprehensive set of research initiatives in GIS covering many different areas. Publications, research reports, outreach activities, and sponsorship of conferences and visitors to the center have been the main activities of the NCGIA.



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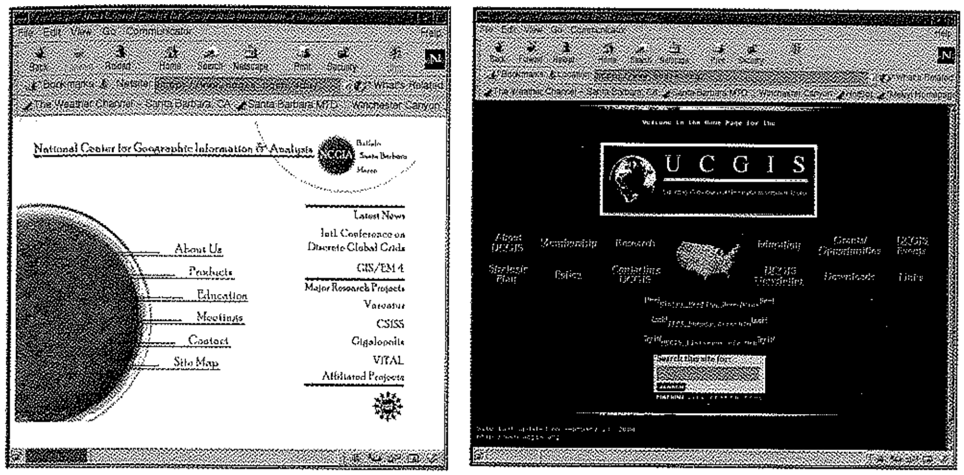

FIGURE 1.8: GIS University Consortia Websites. Left: NCGIA (www.ncgia.uscb.edu). Right: UCGIS (www.ucgis.org).

The primary mission of the NCGIA is to conduct basic research, but the organization also coordinated the formation of a far broader geographic information science community in the United States. In 1994, a total of thirty-three universities, research institutions, and the Association of American Geographers met to establish the University Consortium for Geographic Information Science (UCGIS) (Figure 1.8). UCGIS is a nonprofit organization of universities and other research institutions dedicated to advancing the understanding of geographic processes and spatial relationships through improved theory, methods, technology, and data. As of spring 2000, there were 64 members of the consortium. Several meetings and resource collections have proven very useful as GIS information sources, and the updated list of UCGIS initiatives gives an indication of research directions in GIS.

A college or university near you may be able to provide information about GIS courses or help you to find out more. University libraries hold many GIS publications and conference proceedings, and these are also a good starting point. Perhaps, after reading this book, you will be tempted to take a college course, or maybe you are using this book as part of one. If so, don't forget that learning never ends and that increasing your GIS education also increases your effectiveness as a GIS user, your ability as a geographic information scientist, and your employability as a GIS specialist.

1.5 STUDY GUIDE

1.5.1 Summary

CHAPTER 1: What Is a GIS?

Getting Started (1.1)

- **GIS is built on knowledge from geography, cartography, computer science, and mathematics.**

- **Geographic information science is a new interdisciplinary field built out of the use and theory of GIS.**
- **Different definitions of a GIS have evolved in different areas and disciplines.**
- **All GIS definitions recognize that spatial data are unique because they are linked to maps.**

Some Definitions of GIS (1.2)

- **A GIS at least consists of a database, map information, and a computer-based link between them.**
- **A GIS has been defined as a toolbox for analyzing spatial data.**
- **A GIS has also been defined as an information system for handling spatial data.**
- **Dueker's information systems definition has survived since 1979.**
- **Dueker's definition uses the feature model of geographic space.**
- **The standard feature model divides a mapped landscape into features, which can be points, lines, or areas.**
- **Using a GIS involves capturing the spatial distribution of features by measurement of the world or of maps.**
- **Almost all human activity and natural phenomena are spatially distributed, so they can be studied using GIS.**
- **A GIS uses map features to manage data.**
- **A GIS is flexible enough to be used for ad hoc query and analysis.**
- **A GIS can do analysis, modeling, and prediction.**
- **GIS is an approach to science that crosses several technologies.**
- **Geographic information science is research both on and with GIS.**
- **GIS is a multimillion-dollar business.**
- **Chrisman defines GIS as including the people and institutions that make decisions using geographic measurements and data transformations.**
- **GIS is integrating its way into many aspects of contemporary life.**

A Brief History of GIS (1.3)

- **The origins of GIS lie in thematic cartography.**
- **Many planners employed the method of map overlay using manual techniques.**
- **Manual map overlay as a method was first described comprehensively by Jacqueline Tyrwhitt in a 1950 planning textbook.**
- **McHarg used blacked out transparent overlays for site selection in *Design with Nature*.**
- **The 1960s saw many new forms of geographic data and mapping software.**
- **Within computer cartography the first basic GIS concepts were developed during the late 1950s and 1960s.**
- **Linked software modules, rather than stand-alone programs, preceded GISs.**
- **Early influential data sets were the World Data Bank and the GBF/DIME files.**
- **Early systems were CGIS, MLMIS, GRID, and LUNR.**
- **The Harvard University Odyssey system was influential because of its topological arc/node (vector) data structure.**

- **GIS was significantly altered by both the personal computer and the workstation.**
- **During the 1980s, new GIS software could better exploit more advanced hardware.**
- **User interface developments led to GIS's vastly improved ease of use during the 1990s.**

Sources of Information on GIS (1.4)

- **The large amount of information available about GIS can be overwhelming.**
- **Sources of GIS information include journals and magazines, books, professional societies, the World Wide Web, and conferences.**
- **GIS has Web home pages, network conference groups, professional organizations, and user groups.**
- **Most colleges and universities now offer GIS classes in geography departments.**

1.5.2 Study Questions

GIS Definitions

Summarize the various definitions of a GIS given in this chapter. What are the sources of the definitions? Underline in the definitions terms that are common across the definitions. Why would the definitions reflect different user needs and expectations of what a GIS is and what it can accomplish? How would you expand this set of definitions today?

The History of GIS

Take a look at the online GIS-timeline project, and then draw your own diagram showing a timeline of GIS development. What are the developments that point to a heritage for GIS in various academic disciplines, such as geography, cartography, computer science, environmental science, and planning? Give two examples of ways in which GIS has integrated knowledge and problem solving across these disciplinary boundaries. Search the World Wide Web to find any other GIS timelines. How well does yours agree with any others you may have found?

Sources of Information on GIS

Make a list of the key GIS information sources and find as many as you can in your local public library. If your library offers data services or the Internet, use these to find out as much information about GIS information sources (GIS metadata, or "data about data") as possible. What local, regional, or national GIS meetings or conferences are taking place in your area in the near future? Can you get onto pertinent mailing lists? If possible, arrange a field trip to one of these meetings to see any exhibits and to collect vendor information.

Which colleges, universities, or other educational establishments in your area offer GIS classes? What does the educational establishment teach in the GIS curriculum?

Prepare a two-page "GIS Guide" on finding out about GIS for a complete GIS novice.

1.6 EXERCISES

1. *Use the Internet to search for information about GIS usage and for digital map data online covering your town or city. Are there any attribute data for the maps, perhaps in gazetteers, almanacs, or data books? If you are not connected to the Internet, visit a library and use its facilities, or look in the reference section for information. If you live near a map library, perhaps at a university, see if you can use this facility in your search.*
2. *After a few searches, make an inventory of data you were successful in locating. Put the inventory in the form of a list. Add a column to show which agencies supplied the data you found and how recent the data were. How are the data made available to the public?*
3. *Using the information in this chapter, obtain as much information as possible about the GIS you are or will be using. When was the package created? What is the package's history? Who wrote the software? Are there manuals, research papers, or other sources of information, such as newsletters, user groups, or other manuals, relating to the software of which you are unaware?*
4. *Retrieve the GIS-L FAQ (frequently asked questions) list. How would you get answers to any questions you have at this stage that are not on the list?*
5. *Review the operating system of the computer on which you will work with GIS. Whether it be Unix, Windows, Linux, DOS, or any other, what operations are necessary to create and delete files, create and delete directories, copy and move files, edit the contents of an ASCII file, and use peripheral devices such as CD-ROM drives and plotters or digitizers? Become familiar with the system's manuals and/or online help facility.*
6. *Take a look at the interactive GIS Timeline project on the World Wide Web at* `http://www.casa.ucl.ac.uk/gistimeline`. *What would you consider to be the six most important events in the history of GIS?*

1.7 REFERENCES AND BIBLIOGRAPHY

1.7.1 Books

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1.7.2 Magazines and Journals

Popular Distribution Magazines

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GIS Law. GIS Law and Policy Institute, Suite 501, NationsBank Building, Harrisonburg, VA 22801. Quarterly since 1992.

Geoworld (formerly GIS World), vol. 1, no. 1 (July 1988). Adams Business Media, 250 S. Wacker Drive, Suite 1150, Chicago, IL 60606. E-mail: mball@mail.aip.com Web: `http://www.geoplace.com`.

GPS World Magazine. Avanstar Communications, 859 Willamette Street, Eugene, Oregon 97401-6806 USA. E-mail: editorial-gps@gpsworld.com Web: `http://www.gpsworld.com`.

Mapping Awareness. vol. 7, no. 7 (Sept. 1993). Oxfordshire, UK: Continued as *Mapping Awareness and GIS in Europe*.

Scientific and Academic Journals

Cartographica

Cartographic Perspectives

Cartography and GIS

Computer (algorithms and visualization)

Computers, Environment, and Urban Systems

Computers and Geoscience

Geocarto International

Geographical Systems

GrassClippings

IEEE Transactions on Computer Graphics and Applications (visualization)

IEEE Geosciences

International Journal of GIS

International Journal of Remote Sensing

Landscape Ecology

Photogrammetric Engineering and Remote Sensing

Remote Sensing Review

Transactions in GIS

URISA Journal

1.7.3 Proceedings of Conferences

AUTOCARTO 12, ACSM/ASPRS Annual Convention and Exposition Technical Papers, Charlotte, NC. Feb. 27–Mar. 2, 1995, vol. 4. Continues International Symposium on Automated Cartography.

First International Advanced Study Symposium on Topological Data Structures for Geographic Information Systems. Dedham, MA, 1977. Harvard Papers on Geographic Information Systems: G. Dutton, ed. Cambridge, MA: Laboratory for Computer Graphics and Spatial Analysis, Graduate School of Design, Harvard University, 1978.

GIS/LIS Annual Conference and Exposition. Sponsored by AAG, ACSM, AM/FM, ASPRS, and URISA. Held annually until 1999.

Proceedings, 5th International Symposium on Spatial Data Handling, August 1992, Charleston, SC: IGU Commission on GIS. Held annually.

SSD '95 Advances in spatial databases: 4th International Symposium, Portland, ME, Aug. 6–9, 1995. *Proceedings*, M. J. Egenhofer, and J. R. Herring (eds.). New York: Springer-Verlag. Held biannually.

1.7.4 Professional Organizations

URISA: Urban and Regional Information Systems Association, 900 Second Street NE, Suite 304, Washington, DC 20002. (202) 289-1685. E-mail: urisa@macc.wisc.edu.

AM/FM International: Automated Mapping and Facilities Management, 14456 East Evans Avenue, Aurora, CO 80014. (303) 337-0513.

AAG: The Association of American Geographers, 1710 Sixteenth St. NW, Washington, DC 20009-3198. Also publishes *AAG Newsletter*. (202) 234-1450. E-mail: gaia@aag.org.

ACSM: American Congress on Surveying and Mapping, 5410 Grosvenor Lane, Suite 100, Bethesda, MD. 20814-2122. (301) 493-0200. Web: `http://www.acsm.net`.

ASPRS: American Society for Photogrammetry and Remote Sensing. 5410 Grosvenor Lane, Suite 210, Bethesda, MD 20814-2162. (301) 493-0290.

NACIS: North American Cartographic Information Society, AGS Collection, P.O. Box 399, Milwaukee, WI 53201, (414) 229-6282, fax: (414) 229-3624, E-mail: nacis@nacis.org. See Web Page: `http://www.nacis.org`.

1.7.5 World Wide Web Sites

There are many WWW sites providing information about GIS. These tend to change quite frequently. Links to some of the most useful sites are maintained on the WWW Home Page for Getting Started with GIS at `http://www.prenhall.com/clarke`.

1.7.6 Chapter References

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1.8 KEY TERMS AND DEFINITIONS

academic research: New learning created by the activity of university and other scholars.

ad hoc: For the particular case at hand.

adjacency: The topological property of sharing a common boundary or being in immediate proximity.

analysis: The stage in science when measurements are sorted, tested, and examined visually for patterns and predictability.

arc/node: Early name for the vector GIS data structure.

arc: A line represented as a set of sequential points.

area feature: A geographic feature recorded on a map as a sequence of locations or lines that, taken together, trace out an enclosed area or ring that represents the feature. Example: a lake shoreline.

attribute: A characteristic of a feature that contains a measurement or value for the feature. Attributes can be labels, categories, or numbers; they can be dates, standardized values, field measurements or other data. An item for which data are collected and organized. A column in a table or data file.

AUTOCARTO (International Symposium on Automated Cartography): A sequence of computer cartography and GIS conferences.

cartography: The science, art, and technology of making, using, and studying maps.

CGIS (Canadian Geographic Information System): An early national land inventory system in Canada that evolved into a full GIS.

choropleth map: A map showing numerical data (but not simply "counts") for a group of regions by (1) grouping the data into classes and (2) shading each class on the map.

computer mapping: Producing maps using the computer as the primary or only tool.

connectivity: The topological property of sharing a common link, such as a line connecting two points in a network.

context-sensitive help: A component of a user interface that can reveal to the user information that assists with the current status of other elements of the user interface.

data structure: The logical and physical means by which a map feature or an attribute is digitally encoded.

database: The body of data that can be used in a database management system. A GIS has both a map and an attribute database.

database manager: A computer program or set of programs allowing a user to define the structure and organization of a database, to enter and maintain records in the database, to perform sorting, data reorganization, and searching, and to generate useful products such as reports and graphs.

digitizing tablet: A device for geocoding by semi-automated digitizing. A digitizing tablet looks like a drafting table but is sensitized so that as a map is traced with a cursor on the tablet, the locations are picked up, converted to numbers, and sent to the computer.

Dueker's definition (of GIS): "A special case of information systems where the database consists of observations on spatially distributed features, activities or events, which are definable in space as points, lines, or areas. A geographic information system manipulates data about these points, lines, and areas to retrieve data for ad hoc queries and analyses."

FAQ: A list of frequently asked questions, usually posted on a network newsgroup or conference group to save new users the trouble of asking old questions over again.

feature: A single entity that makes up part of a landscape.

file: Data logically stored together at one location on the storage mechanism of a computer.

format: The specific organization of a digital record.

FORTRAN: An early computer programming language, initially for converting mathematical formulas into computer instructions.

fourth dimension: A common way of referring to time; the first three dimensions determine location in space, the fourth dimension determines creation, duration, and destruction in time.

functional definition: Definition of a system by what it does rather than what it is.

g-trade: (also g-commerce): Web-oriented use of GIS capability to spatially enable the search and browse processes during online business activity or e-trade.

GBF (Geographic Base File): A database of DIME records.

general-purpose map: A map designed primarily for reference and navigation use.

geocoding: The conversion of analog maps into computer-readable form. The two usual methods of geocoding are scanning and digitizing.

geographic information science: Research on the generic issues that surround the use of GIS technology, impede its implementation, or emerge from an understanding of its capabilities.

geographic(al) information system: (1) A set of computer tools for analyzing spatial data; (2) a special case of an information system designed for spatial data; (3) an approach to the scientific analysis and use of spatial data; (4) a multibillion-dollar industry and business; (5) a technology that plays a role in society.

geographic pattern: A spatial distribution explainable as a repetitive distribution.

geography: The science concerned with all aspects of the earth's surface, including natural and human divisions, the distribution and differentiation of regions, and the role of humankind in changing the face of the earth.

GIS/LIS: A U.S. national conference on geographic information and land information systems, sponsored by most GIS professional organizations and held annually.

GUI (graphical user interface): The set of visual and mechanical tools (such as window, icons, menus, and toolbars, plus a pointing device such as a mouse) through which a user interacts with a computer.

information: The part of a message placed there by a sender and not known by the receiver.

information system: A system designed to allow the user to be delivered the answer to a query from a database.

installed base: The number of existing implemented systems.

Internet: A network of many computer networks. Any computer connected to the Internet can access any of the computers accessible through the network.

isoline map: A map containing continuous lines joining all points of identical value.

killer app: A computer program or "application" that by providing a superior method for accomplishing a task in a new way becomes indispensable to computer users. Examples are word processors and spreadsheets.

land-cover map: A map showing the type of actual surface covering at a given time. Categories could be grassland, forest land, cropland, bare rock, and so on.

land-use map: A map showing the human use to which land is put at a given time. Categories could be pasture, national forestland, agricultural land, wasteland, and so on.

landscape: The part of geographic space shown on a map, including all its features.

learning curve: The relationship between learning and time. A steep learning curve means that much is learned quickly (usually thought to be the opposite). A difficult learning curve is one where learning takes place slowly, over a long time period.

line feature: A geographic feature recorded on a map as a sequence of locations tracing out a line. An example is a stream.

LIS (land information system): Surveying profession's term for GIS where that data are for land ownership.

location: A position on the earth's surface or in geographic space definable by coordinates or some other referencing system, such as a street address or space indexing system.

LUNR (Land Use and Natural Resources Inventory System): An early GIS in New York.

map: A depiction of all or part of the earth or other geographic phenomenon as a set of symbols and at a scale whose representative fraction is less than 1 : 1. A digital map has had the symbols geocoded and stored as a data structure within the map database.

map overlay: Placing multiple thematic maps in precise registration, with the same scale, projections, and extent, so that a compound view is possible.

measurement: A quantitative assessment of a phenomenon.

menu: A component of a user interface that allows the user to make selections and choices from a preset list.

MIMO system: A term used to describe a first-generation computer mapping system designed to capture the map by computer and reproduce it (map in–map out).

MLMIS (Minnesota Land Management System): An early statewide GIS for the state of Minnesota.

modeling: The stage in science when a phenomenon under test is sufficiently understood that an abstract system can be built to simulate the real system.

modular computer program: Computer programs composed of integrated sections of reusable functions rather than a single program.

National GIS Curriculum: An NCGIA-sponsored national college curriculum for GIS, used in many colleges and universities worldwide and with available teaching materials.

National Spatial Data Clearinghouse: A World Wide Web resource that serves as a cross-reference point for the distributed database of all U.S. government public-domain and other geographic information.

NCGIA (National Science Foundation's National Center for Geographic Information and Analysis): A three-university consortium funded to assist in GIS education, research, outreach, and information generation.

newsgroup: An area on the Internet for asynchronous many-to-many discussions.

node: At first, any significant point in a map data structure. Later, only those points with topological significance, such as the ends of lines.

observation: The process of recording an objective measurement.

Odyssey: A first-generation GIS developed at Harvard to implement the original arc/node vector data structure.

online manual: A digital version of a computer application manual available for searching and examination as required.

overlay weighting: Any system for map overlay in which the separate thematic map layers are assigned unequal importance.

PC (Personal Computer): A self-contained microcomputer, providing the necessary components for computing, including hardware, software, and a user interface.

point feature: A geographic feature recorded on a map as a location. Example: a single house.

prediction: The scientific ability to forecast the outcome of a process in advance.

proceedings: The formal record of the papers and other prepared presentations at a conference. Usually available to conference attendees and later distributed as a softcover book.

professional publication: Books, journals, or other information designed primarily for those using GIS technology as part of their job.

query: A question, especially if asked of a database by the user via a database management system or GIS.

record: A set of values for all attributes in a database. Equivalent to a row in a data table.

scientific approach: A method for rationally explaining observations about the natural and human world.

search engine: A software tool designed to search the Internet and the WWW for documents meeting the user's query. Examples: Yahoo and Alta Vista.

software package: A computer program application.

spatial data: Data that can be linked to locations in geographic space, usually via features on a map.

spatial distribution: The locations of features or measurements observed in geographic space.

spreadsheet: A computer program that allows the user to enter numbers and text into a table with rows and columns and then maintain and manipulate those numbers using the table structure.

thematic map: A map designed primarily to show a "theme," a single spatial distribution or pattern, using a specific map type.

topographic map: A map type showing a limited set of features but including, at the minimum, information about elevations or landforms. Example: contour maps. Topographic maps are common for navigation and for use as reference maps.

topology: The numerical description of the relationships between geographic features, as encoded by adjacency, linkage, inclusion, or proximity. Thus a point can be inside a region, a line can connect to others, and a region can have neighbors.

transparent overlay: An analog method for map overlay, where maps are traced or photographed onto transparent paper or film and then overlain mechanically.

U.S. Census Bureau: An agency of the Department of Commerce that provides maps in support of the decennial (every 10 years) census of the United States, especially the census of population.

user group: Any formal or informal organization of users of a system who share experiences, information, news, or help among themselves.

USGS (U.S. Geological Survey): A part of the Department of the Interior and a major provider of digital map data for the United States.

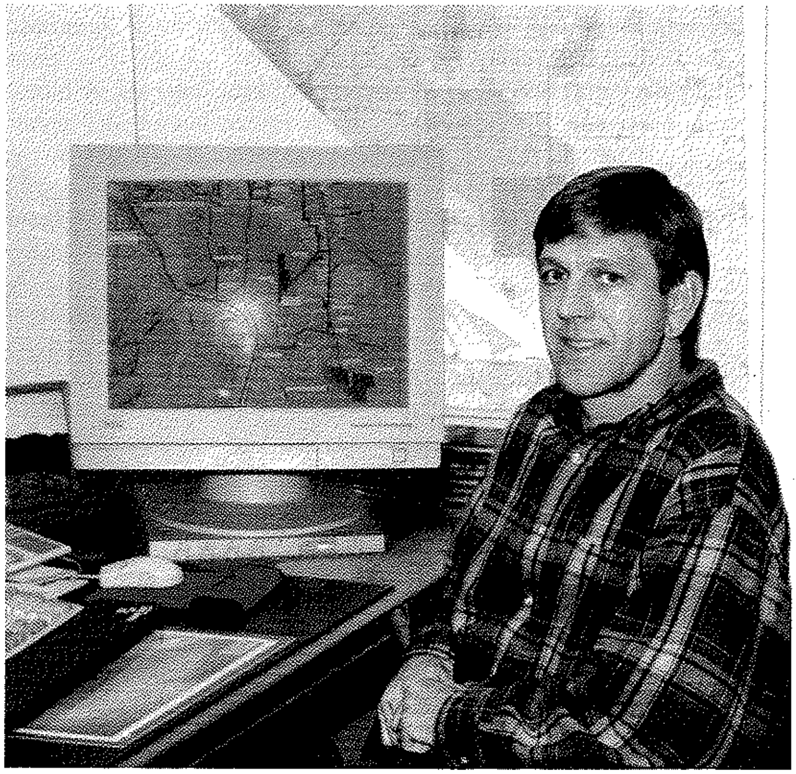
vector: A map data structure using the point or node and the connecting segment as the basic building block for representing geographic features.

workstation: A computing device that includes, as a minimum, a microprocessor, input and output devices, a display, and hardware and software for connecting to a network. Workstations are designed to be used together on local area networks, and to share data, software, and so on.

World Data Bank: One of the first digital maps of the world, published in two versions by the Central Intelligence Agency in the 1960s.

World Wide Web (WWW or W3): A distributed database of information stored on servers connected by the Internet.

PEOPLE IN GIS



Nils Larsen GIS Coordinator and Staff Geologist

Nils Larsen has been GIS Coordinator and Staff Geologist at IWT, Inc. in Santa Barbara for the last seven years. A native of the Seattle area, his background is in geology, with a Bachelor of Science degree at Western Washington University. Nils moved to California and started working as a soils technician in a soils lab before taking a position at a hydrologic consulting firm, IWT. As the firm became more and more involved in GIS, Nils became responsible for making GIS work in the consulting activity of the company, with a continuing focus on water and the use of digital information in resource exploration.

KC: Nils, did you use computers in college?

NL: There was one programming class in Pascal. I took geography courses in map reading and analysis, where I spent time with paper maps, learning what's on them and how they're put together, what the information means. I've always been interested in maps.

KC: What sort of clients does your company have?

NL: Two main types of clients: private companies that want to develop or to invest in water resource assets or water rights. We do the water resource investigations, finding out how much there is associated with a particular piece of property, then they can decide if they want to purchase that land. Our public clients are typically water districts, water service agencies, and so forth. We help them manage the water resources that they have,

t IWT, Inc. in Santa Barbara kground is in geology, with a ity. Nils moved to California taking a position at a hydro- l more involved in GIS, Nils activity of the company, with tion in resource exploration.

ı types of clients: private com- ant to develop or to invest in e assets or water rights. We do urce investigations, finding out ere is associated with a partic- property, then they can decide o purchase that land. Our pub- typically water districts, water es, and so forth. We help them ater resources that they have,

find out where the water's coming from, how much is going into the system, where it's getting taken out, where there are contamination problems or overdraft problems.

KC: Those problems are related to the subsurface geology and flow within that complicated structure?

NL: Definitely. The GIS is very helpful for visualizing those problems relative to the geologic structure. We worked for a Water Conservation District in the local area who operate some artificial recharge basins, and also have sea water intrusion and water quality problems. The GIS was instrumental in showing the relationships between them.

KC: What brought you into GIS in your field?

NL: Well, at IWT, we wanted to try and get a jump on some of the competition so we decided to invest in GIS. We had what we thought was somewhat of a specialized field—water resource investigations in fractured bedrock, beyond drilling wells into alluvial basins. The option was whether to go PC-based or workstations. We use NT workstation PCs and some Windows 95 PCs; lots of memory, lots of storage space. We use a large format plotter, a large digitizing tablet and a flatbed scanner.

KC: And what GIS software did you use?

NL: The original suite of software was ArcCad and AutoCad 12, all in DOS then ArcView 1 and an AutoCad third party package called Quicksurf.

KC: With a scanner and a digitizing tablet you must digitize maps. What kind?

NL: Just about anything that's not in digital form. We've captured data from geologic maps and consulting firms' reports, and from blue-line maps typical of engineering firms.

KC: Is it hard to georegister so many different maps?

NL: The difficulty is when there's no projection or coordinate system on the map. Those are typically blue-line, engineering type maps.

KC: What sort of attribute data do you bring into GIS that you might use in combination with the maps?

NL: If I'm working with well data, then depth, well diameter, water levels, water quality, well perforation interval, aquifer, well ID, owner. These are all typical attributes. For geologic data we use things like the formation name, rock type, age, and different levels of classification, such as formation subunits.

KC: If you were going to give advice to an intern or an incoming freshman, what would it be?

NL: Get to know the paper maps, get to know projection systems, datums, the different kinds and why certain ones are used for certain reasons. Area versus shape versus direction issues regarding different projection systems. As well, learn how to read manuals and spend time reading manuals.

KC: Thanks very much Nils.

(Interview and photograph used with permission of Nils Larsen)