



# Beyond Mapping Compilation Series

by Joseph K. Berry

...Beyond Mapping columns appearing in [GeoWorld](#) (formally GIS World) magazine from **March 1989** through **December 2013** ([www.innovativegis.com/basis/BeyondMappingSeries](http://www.innovativegis.com/basis/BeyondMappingSeries/))

Most GIS applications have focused on mapping and spatial data management for viewing and geo-query of mapped data. Map analysis and GIS modeling involve entirely new spatial reasoning concepts and procedures that are not reflected in our paper map legacy. The books in the Beyond Mapping Compilation Series are based on Joe Berry's popular "Beyond Mapping" columns in GIS World/GeoWorld magazine that discuss the new breed of map analysis tools, how they can be used to better characterize and communicate spatial relationships, be organized into effective GIS model solutions, and spark entirely new spatial paradigms. The topics covered in the series are written for novices, as well as GIS professionals, in a witty style that entertains as well as informs.

The real estate axiom of "location, location, location" has moved to the forefront of understanding and interacting with our world. Prior to the digital map, spatial information was constrained to the "precise placement of physical features" primarily for navigation, inventory and recordkeeping. Today, the historical objective of "Where is What" has been expanded to "Why, So What and What If" investigations of the spatial patterns and relationships driving our physical, ecological, economic, social and political systems. Geotechnology (RS, GIS, GPS) has ushered in an bold new era of mapped data visualization, interactive geo-query and quantitative analysis of mapped data supporting spatial communication, reasoning and dialog— "**thinking with maps.**"

The nearly 1000 pages and more than 750 figures in the Beyond Mapping Compilation Series provides a comprehensive and longitudinal perspective of the underlying concepts, considerations, issues and evolutionary development of modern geotechnology.



The columns forming the Beyond Mapping Compilation Series are organized into

## **Four Online/Electronic/Hardcopy Books**

each with Introduction, Ten Topics, Epilog and Further Readings

...also with links to online support materials including additional Online Readings, Color Graphics files, Instructor Materials and Software for "hands-on" exercises that are cross-referenced to the topics in the series

**Beyond Mapping Book IV — [GIS Modeling: Applying Map Analysis Tools and Techniques](#)** is an online/electronic book organizing the columns from **2007 to 2013** that extends earlier discussions of map analysis concepts, procedures, approaches, applications and issues affecting contemporary relevance and future directions of geotechnology.

**Beyond Mapping Book III — [Map Analysis: Understanding Spatial Patterns and Relationships](#)** is an online/hardcopy book organizing the columns from **1996 to 2007** that develops a structured view of the important concepts, considerations and procedures involved in grid-based map analysis.

**Beyond Mapping Book II — [Spatial Reasoning for Effective GIS](#)** is an online/hardcopy book organizing the columns from **1993 to 1996** that explores the basic concepts of map analysis and discusses the fundamental elements of GIS that make it different from traditional map structure, content, processing and use while encouraging the reader to extend the historic role of maps telling us "Where is What?" to "So What?"

**Beyond Mapping Book I — [Beyond Mapping: Concepts, Algorithms and Issues in GIS](#)** is an online/hardcopy book organizing the columns from **1989 to 1993** that introduces the concepts of geographic information systems (GIS) technology and discusses the issues involved as GIS moves from the researcher to the general user.

Navigation within the tsunami of information in the Series is aided by five separate organizational listings of the individual Beyond Mapping columns—

[Chronological Listing](#) of the nearly 300 individual Beyond Mapping columns (.html and .pdf)

[Application Listing](#) that organizes the columns by application areas (.html and .pdf)

[Operations Listing](#) that organizes the columns by topic/theme discussed (.html and .pdf)

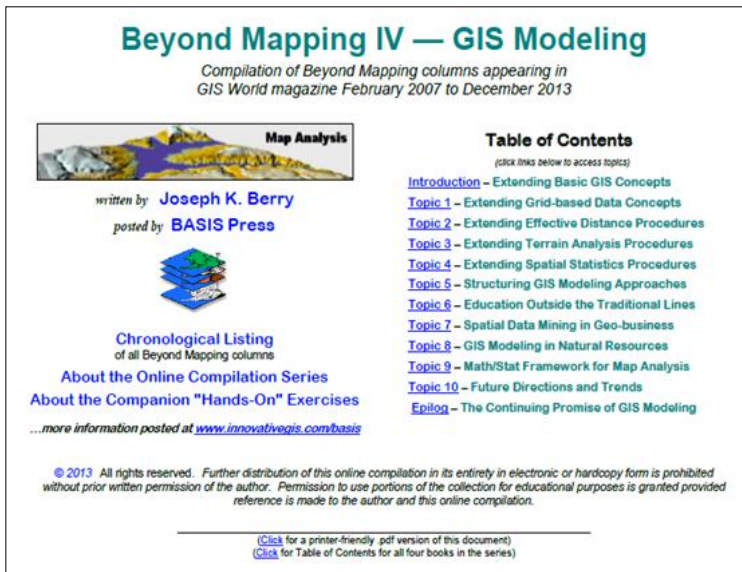
[Interactive Listing](#) that can be searched/sorted by any word or phrase, topic, theme and application area (Word .doc)

[Combined Index](#) of keywords and phrases covering all four books (.html...in progress; planned for Fall 2014)

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## Beyond Mapping Compilation Series (Book IV)

# GIS Modeling: Applying Map Analysis Tools and Techniques



**GIS Modeling: Applying Map Analysis Tools and Techniques** is a collection of selected works from Joe Berry's popular "Beyond Mapping" columns published in GeoWorld magazine from 2007 through 2013.

This compilation extends earlier discussions of map analysis concepts, procedures, approaches, applications and issues affecting contemporary relevance and future potential.

Geotechnology (the spatial triad of remote sensing (RS), GIS and GPS) has "taken to the net" and become routine in most workplaces and general users' computers, tablets and mobile devices. As a ubiquitous "technological tool," it has become an indispensable part of daily life and interwoven into the fabric of modern society.

Geotechnology's expression as an "analytical tool" is poised for a similar run and promises to forever change

how people perceive geographic space and its intersection with numeric space to understand spatial relationships without the simplifying assumptions previously found in science and practice before the digital map. **This transformative book is sure to alter experienced and novice readers' perceptions and paradigms of "what a map is (and isn't)" and how mapped data can be analyzed for startling new revelations of the world around us.**

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## Book IV — Table of Contents

**Introduction** Extending Basic GIS Concepts — Comparing paper and digital map worlds identifies an entirely new beast that supports radically new mapping approaches, perspectives and opportunities with all the rights, privileges and responsibilities of traditional quantitative data analysis. This section explores the differences in vector and raster data forms, their implications for resolving spatial detail, and the rethinking of geo-referencing schema.

**Topic 1** Extending Grid-based Data Concepts — Grid-based raster maps store a map value at each location in a matrix to identify the characteristic/condition occurring at that grid cell. This topic describes how individual *map layers* are assembled into georegistered *map stacks*, defining the continuous distribution of each *map variable* for use in the quantitative analysis of mapped data (*Spatial Analysis* and *Spatial Statistics*) that's a direct extension of nonspatial math/stat procedures.

**Topic 2** Extending Effective Distance Procedures — Effective distance considers intervening absolute and relative barriers in characterizing movement through geographic space. This topic describes the underlying concepts and basic approaches used to establish variable-width buffers, travel-time surfaces and optimal path routing as well as contiguity and narrowness measures.

**Topic 3 Extending Terrain Analysis Procedures** — Terrain analysis, one of the oldest applications of grid-based map analysis, characterizes the relative steepness and directional orientation of an elevation surface. This topic investigates additional techniques for landscape segmentation, determining longitudinal and transverse slopes of linear features, identifying upland ridges, and determining uphill/downhill/across portions and line-of-sight connectivity within roving windows.

**Topic 4 Extending Spatial Statistics Procedures** — Spatial Statistics relaxes the assumption that a “typical value” (e.g., average) is evenly distributed over a project area to characterize the continuous spatial distribution of field data, using such information to assess relationships within and among various map layers. This topic establishes the underlying concepts and procedures for developing spatial distributions, and then extends traditional nonspatial techniques into the spatial realm, such as generating maps of localized variations in Correlation and T-test.

**Topic 5 Structuring GIS Modeling Approaches** — Grid-based *GIS Modeling*, in many respects, is an extended form of traditional mathematical modeling that manipulates matrices representing the spatial distribution of map variables. This topic examines the “map-ematical structure” for processing map layers, data-handling approaches, concerns surrounding precision and accuracy, and the similarities and differences among different types of GIS models.

**Topic 6 Education Outside Traditional Lines** — GIS education has evolved significantly during four decades, with an early focus on training GIS specialists needed for transforming paper map information, procedures and mindsets into digital forms. More recently, education has broadened its focus to innovative solutions involving domain experts from a multitude of disciplines and incorporating rapidly evolving technological advances. This topic discusses the different perspectives of “the trailing ‘S’ in GIS” (Systems, Specialist, Science and Solutions), its impacts on GIS education and the probable increased emphasis on nontraditional GIS students in developing “spatial-reasoning” skills across campus.

**Topic 7 Spatial Data Mining in Geo-business** — Maps historically had minimal application in business operations, planning and decision making. However, with the advent of digital mapped data analysis/modeling, a more thorough understanding of spatial patterns and relationships are proving critical in successful marketing, financial, logistical and managerial actions. This topic links numerical and spatial distributions to uncover “unusual response” areas, identifies areas having relative similarity and clustering tendencies, and describes a Universal Database Key that promises to revolutionize database technology.

**Topic 8 GIS Modeling in Natural Resources** — Maps and mapping have long been a cornerstone of natural-resources management. However, map analysis/modeling capabilities have extended the traditional “where is what” spatial inventories to “why, so what and what if” understandings of spatial interactions among critical factors that are radically changing natural-resources research, policy formation, decision making and operations. This topic examines the use of *Effective Distance* to generate more realistic assessments of forest access for harvesting and emergency response, and then extends the discussion to how spatial technology promises to change the natural-resources paradigm.

**Topic 9 Math/Stat Framework for Map Analysis** — Map Analysis and GIS Modeling are poised to radically change science, technology, engineering and math (STEM) curricula at the K-12 and college levels by infusing spatial reasoning and analysis into traditional classroom settings. This topic establishes a generalized math/stat framework that directly extends current quantitative data-analysis procedures into the spatial realm by considering maps as “spatially organized data layers” (as opposed to graphical images) that have all the rights, privileges, responsibilities and analytical potential of traditional nonspatial data.

**Topic 10 Future Directions and Trends** — Geotechnology’s only consistent element is its ability to change. In just four decades, it has evolved from automated cartography to spatial database technology to analytic engine operating with mapped data and software in the cyber-cloud. This topic suggests a probable future that dramatically alters perspectives of “what a map is and isn’t” by expanding the flat 2-D (x,y) view of geographic space to a 3-D (x,y,z) and 4-D (x,y,z,time) view by fundamentally changing the 300-plus-year-old Cartesian referencing system.

**Epilog The Continuing Promise of GIS Modeling** — Geotechnology has great potential for good (and bad). This topic discusses the good, the bad and the ugly sides of geotechnology, with particular attention to enduring impacts on how people perceive, process, promote and practice innovative ways to understand the spatial patterns and relationships that impact all systems (physical, climatic, biological, economic, political, social and cultural).



Beyond Mapping Compilation Series




## Beyond Mapping Compilation Series (Book III)


# Map Analysis: Understanding Spatial Patterns and Relationships

### Beyond Mapping III — Map Analysis

Compilation of Beyond Mapping columns appearing in GIS World magazine September 1996 to January 2007



Map Analysis  
written by **Joseph K. Berry**  
posted by **BASIS Press**



Chronological Listing  
of all Beyond Mapping columns  
About the Online Compilation Series  
About the Companion "Hands-On" Exercises  
...more information posted at [www.innovativegis.com/basis](http://www.innovativegis.com/basis)

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#### Table of Contents

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**Map Analysis: Understanding Spatial Patterns and Relationships** is a collection of selected works from of Joe Berry's popular "Beyond Mapping" columns published in GeoWorld magazine from 1996 through 2007. This compilation develops a structured view of the important concepts, considerations and procedures involved in grid-based map analysis.

While numerous books focus on Geographic Information Systems (GIS) capabilities of computer mapping and spatial database management, few provide an understanding of its analytical potential and practical realities in a non-technical manner. The unique character of the Map Analysis book draws from the author's ability to convey seemingly complex concepts of spatial data and GIS operations in words that resonant with others less technically versed.

The result is a book that engages the reader to "think spatially" and formulate new and innovative solutions to

complex spatial problems. Key to this process is a paradigm shift that extends the traditional paper map perspective of "where is what" to the modern perspective of "why and so what." Within this context, maps become data and map analysis becomes the means to derive information about spatial patterns and relationships within and among map layers.

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## Book III — Table of Contents

**Introduction The GIS Evolution** — As GIS moves from graphical inventories and spatial databases to map analysis, an entirely new paradigm of mapping is emerging. This topic discusses the relatively short history, evolutionary trajectory and probable future of geotechnology.

**Topic 1 Data Structure Implications** — GIS technology is as different as it is similar to traditional mapping. These differences are due in large part to the structure and nature of digital mapped data. This topic describes the various data and display types and their impacts on the appropriate characterization of discrete and continuous geographic distributions/patterns.

**Topic 2 Fundamental Map Analysis Approaches** — Map Analysis exploits the digital nature of modern maps to investigate the patterns and relationships within and among mapped data. This topic uses a series of examples to introduce the concept of a map-ematics and the similarities/differences in *Spatial Analysis* and *Spatial Statistics* that form the two primary compartments of the map analysis toolbox.

**Topic 3 Basic Techniques in Spatial Analysis** — Spatial Analysis investigates the "spatial context" of mapped data resulting from the relative positioning and coincidence of the map values. This topic discusses the *Reclassify* and *Overlay* grouping of operators that form the basic techniques used in most spatial models.

**Topic 4 Calculating Effective Distance** — Traditional “as the crow flies” distance measured with a ruler is rarely an effective in establishing separation between two points as the reality of intervening barriers play a significant role that bends and twists actual movement. This topic discusses the advanced *Distance Measurement* grouping of operators and expands the concept of simple distance to effective proximity considering relative and absolute barriers to movement.

**Topic 5 Calculating Visual Exposure** — Visual analysis is an extension of effective distance measurement that considers line-of-sight connectivity among map locations. This topic discusses the procedures, considerations and applications of derived viewshed and visual exposure maps.

**Topic 6 Summarizing Neighbors** — Values surrounding a location can be used to investigate localized variation, anomalies, and trends in mapped data. This topic discusses the advanced Neighbors grouping of operators that characterize map values occurring within a roving window centered at a location by either the surface configuration implied or a simple statistical summary.

**Topic 7 Basic Spatial Modeling Approaches** — Spatial Modeling involves “thinking with maps” to solve a problem by deriving a solution map through a logical series of map analysis operations applied to base maps in a manner analogous to a cooking recipe. This topic describes a progression of models that demonstrate the procedures and considerations in deriving areas of suitable wildlife habitat.

**Topic 8 Spatial Modeling Example** — Successful spatial models require the integration human judgment and analytical processing. This topic describes the spatial reasoning and processing considerations surrounding a routing model that considers preferences for a variety of map criteria in determining the best path and optimal corridor for a proposed power line.

**Topic 9 Basis Techniques in Spatial Statistics** — *Spatial Statistics* utilizes information about the spatial arrangement inherent in a data set to help explain variation and is based on the assumption that “nearby things are more alike than distant things.” This topic focuses on surface modeling techniques used to generate and evaluate the geographic distribution implied by a set of discrete point samples.

**Topic 10 Spatial Data Mining** — Spatial Data Mining investigates the relationships within and among mapped data to characterize, compare, segment and map-ematically model spatial dependency. This topic focuses on basic techniques for comparing maps, assessing similarity and clustering as means to understand and utilize spatial relationships in decision-making.

**Epilog The Many Faces of GIS** — GIS in general and map analysis in particular is radically changing how we perceive and utilize maps. This topic discusses different GIS adoption paths, their driving factors and impacts on the current and future dynamics within the GIS community.

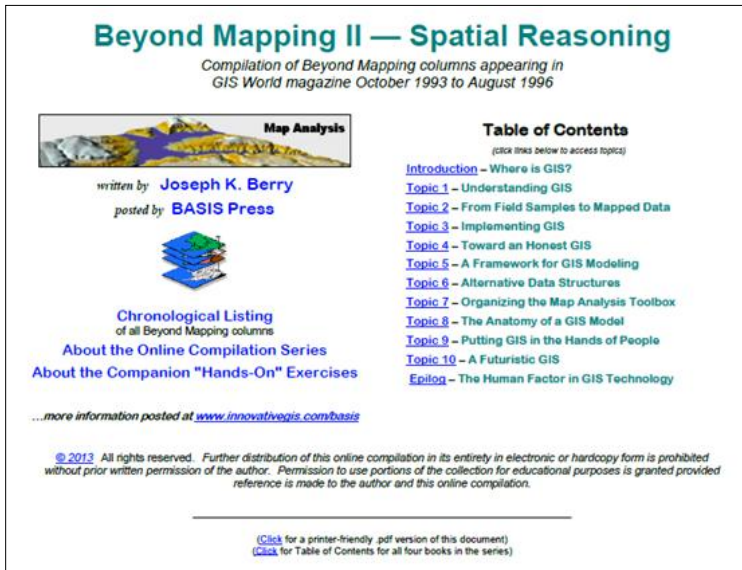


Beyond Mapping Compilation Series

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## Beyond Mapping Compilation Series (Book II)

# Spatial Reasoning for Effective GIS Solutions



*Spatial Reasoning for Effective GIS Solutions is a collection of selected works from of Joe Berry's popular "Beyond Mapping" columns published in GeoWorld magazine from 1993 through 1996.*

*This compilation explores the basic concepts of map analysis and discusses the fundamental elements of GIS that make it different from traditional map structure, content, processing and use.*

*It is an invitation to consider the expanded capabilities of GIS and relate them to current operations thereby fostering an appreciation of GIS as an effective analytical tool in solving many complex spatial issues. GIS is a new technology, and as such it presents new opportunities as well as new pitfalls.*

*This book engages the reader (both specialist and general user) through incisive and relaxed discussion*

*that investigates why GIS technology is "as different from as it is similar" to traditional map processing. We are at the threshold of a new era— one that directly incorporates the complexity of geographic space in decision-making instead of simply applying a single solution throughout an entire area. The step isn't so much rocket science as it is a new approach to problem solving. Sure, there are new and initially confusing tools, but the real challenge is in "thinking spatially."*

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## Book II — Table of Contents

**Introduction Where is GIS?** — Is the GIS technology cart in front of the horse? Data mining, predictive modeling and dynamic simulation are new applications of GIS used to uncover spatial relationships and sensitivities among mapped data. This section discusses the revolutionary procedures identifying the driving forces, trends and forecasts of the spatial paradigm.

**Topic 1 Understanding GIS** — As GIS moves from graphical inventories to spatial reasoning, new procedures must be developed to communicate the logic that supports GIS models. An end user must interact with a model—a spatial spreadsheet—that can present alternative perspectives. This section describes the interactive use of a map pedigree linking GIS commands to a flowchart of model logic.

**Topic 2 From Field Samples to Mapped Data** — In the simplest sense, statistics are merely a collection of numbers. Traditional statistical analysis characterizes the "typical response" in a data set; whereas spatial statistics seek to map the data's distribution in geographic space. This section compares the two approaches and investigates various techniques of spatial interpolation.

**Topic 3 Implementing GIS** — GIS technology begins with a thorough understanding of its intended applications and operating environment. This section presents an applications-driven procedure for assessing GIS information needs within an organization and establishes a hierarchy of questions it can address.

**Topic 4 Toward and Honest GIS** — By their nature, maps are abstractions of real conditions. They approximate the positioning of tangible or conceptual features on our landscape with varying degrees of certainty. This section introduces the concept of using a "shadow map" of certainty to track error propagation in GIS models.

**Topic 5 A Framework for GIS Modeling** — The use of GIS to model complex spatial relationships is increasing rapidly. Our understanding of the types and approaches of models, however, is based on decades of nonspatial modeling experience. This section presents a classification framework for GIS models and a flowcharting methodology.

**Topic 6 Alternative Data Structures** — At the heart of GIS is data. How data are structured, in large part, determines a system's performance, capabilities and breadth of applications. This section describes alternative approaches to vector and raster data structures.

**Topic 7 Organizing the Map Analysis Toolbox** — What GIS can do depends on the depth of the spatial information available to the computer, tempered by the depth of understanding of the analytical operations by those who use it. This section discusses spatial topology and its extension to the classification of analytical GIS operations.

**Topic 8 The Anatomy of a GIS Model** — Although GIS models address a wide diversity of applications, the basic structure of most models are quite similar. This section compares several GIS models to illustrate different modeling approaches and varying levels of results they generate.

**Topic 9 Putting GIS in the Hands of People** — The Global Positioning System (GPS) focuses on real-time positioning in space while remote sensing (RS) technology focuses on monitoring and classifying the landscape. This section covers the underlying principles of these related fields and their integration into a GIS/GPS/RS field unit.

**Topic 10 A Futuristic GIS** — Spatial Analysis is more than mapping and spatial database management. It involves deriving new information to express relationships based on the relative positions of map features. This section establishes a framework for spatial analysis and demonstrates several of its import aspects.

**Epilog The Human Factor in GIS Technology** — GIS technology is thought of as hardware and software. However, the "humanware" component often determines the usefulness of the system. This section discusses the human factor in GIS and the linkages and distinctions among data, information, knowledge and wisdom.



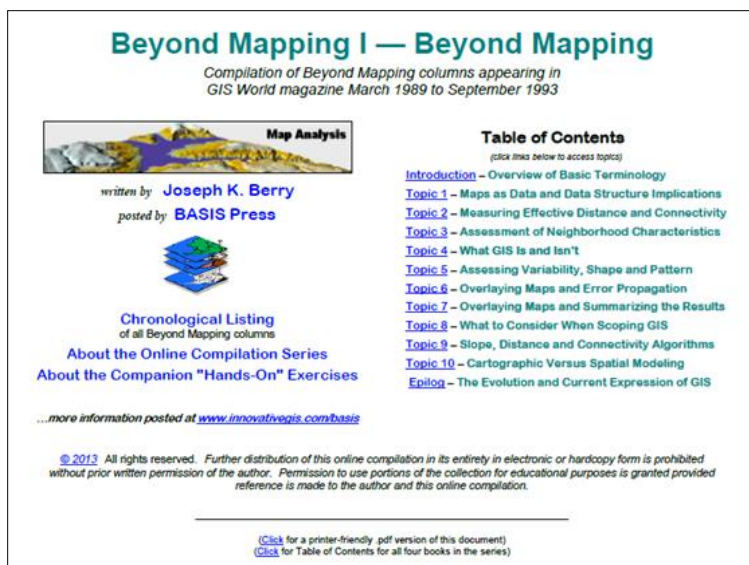
**Beyond Mapping Compilation Series**

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## Beyond Mapping Compilation Series (Book I)

# Beyond Mapping: Concepts, Algorithms and Issues in GIS



***Beyond Mapping: Concepts, Algorithms and Issues in GIS*** is a collection of Joe Berry's popular "Beyond Mapping" columns published in *GIS World* from 1989 to 1993.

*In this compilation, Berry explores the concepts of geographic information systems (GIS) technology and discusses the issues involved as GIS moves from the researcher to the general user.*

*However, the current user community tends to define GIS in comfortable terms of computer mapping and spatial database management. While these basic activities are the cornerstones of GIS and automate our historic map analysis procedures, this "paper map" perspective severely limits the full potential of this new digital map technology.*

*This emerging technology goes beyond traditional mapping and spatial database management to new*

*concepts and procedures for modeling the complex interrelations among spatial data of all kinds.*

*This book is designed so the general user can read about broad issues and then delve into more detail, even to the algorithm level. Berry's witty writing style is sure to inform as it entertains both the GIS professional as well as the novice who is beginning a journey in this new technology.*

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## Book I — Table of Contents

**Introduction Overview of Basic Terminology** — There are some similarities, but many differences, between traditional and GIS maps. This section describes the conceptual differences and terminology used in vector and raster map formats and an overall organizational structure for GIS databases.

**Topic 1 Maps As Data and Data Structure Implications** — The full impact of numerical representation of spatial data in GIS is just beginning to be recognized. In this section the implications of vector and raster data models on encoding, storage, and analysis are discussed. The inherent statistical characterizations of mapped data and their implications in map analysis are described.

**Topic 2 Measuring Effective Distance and Connectivity** — Before GIS technology, the concept of distance was as simple and straightforward as a ruler. Now the traditional concept of distance is first extended to one of proximity, then to one of actual movement in geographic space, around and through barriers. Procedures and applications of optimal path analysis over continuous map surfaces also are presented.



**Topic 3 Roving Windows: Assessment of Neighborhood Characteristics** — Information surrounding a point often provides insight into spatial problem solving. Neighborhood summaries can be derived from surface configuration to produce slope, aspect and profile maps. Or, the summaries can relate to the context of the neighborhood for such procedures as spatial interpolation, smoothing, and diversity analysis. More than any other classes of operations, “roving windows” provide entirely new applications for map analysis.

**Topic 4 What GIS Is and Isn't: Spatial Data Mapping, Management, Modeling and More** — Most initial applications of GIS automate current cartographic practices. However, the greatest return on investment in GIS technology is realized through entirely new applications inspired by the new set of map analysis tools. This section develops an awareness of the considerations and conditions that move user perspective from computer mapping to spatial database management to application modeling and beyond.

**Topic 5 Assessing Variability, Shape, and Pattern of Map Features** — The shape and pattern of landscape features are readily apparent to the eye but historically difficult to quantify. This section describes several indices used in characterizing the configuration and arrangement of features.

**Topic 6 Overlaying Maps and Characterizing Error Propagation** — Overlaying maps is at the heart of most GIS applications. However, the propagation of errors needs to be characterized and included with the overlay results. This section describes approaches used in establishing map uncertainty and assessing error propagation.

**Topic 7 Overlaying Maps and Summarizing the Results** — In GIS overlaying maps goes beyond traditional procedures of “sandwiching” map sheets on a light-table. In this section, procedures for point-by-point, region-wide, and map-wide overlay summaries are described. Numerous applications and the underlying concepts are presented.

**Topic 8 Scoping GIS: What to Consider** — GIS technology is a radical departure from traditional map processing; therefore, assessing its potential within an organization needs to go beyond traditional cost-benefit analysis. This section describes the major organizational, social, and personal ramifications of implementing GIS.

**Topic 9 Slope, Distance and Connectivity: Their Algorithms** — At first encounter, many of the advanced GIS analytical operations are intimidating. However, a basic understanding of the computer's procedures is needed to assess the potential and limitations of the new tools. This section describes various approaches used in computing slope, effective distance, optimal paths and visual connectivity.

**Topic 10 Cartographic and Spatial Modeling** — Many GIS applications take the technology well beyond mapping and into the larger field of mathematical modeling. This section discusses command “macro” construction, the mathematical implications, and the use of GIS models in consensus building and conflict resolution.

**Epilog The Evolution and Current Expression of GIS** — We have been creating and using mapped for thousands of years. This section looks at GIS's history, current trends and probable future.



Beyond Mapping Compilation Series

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