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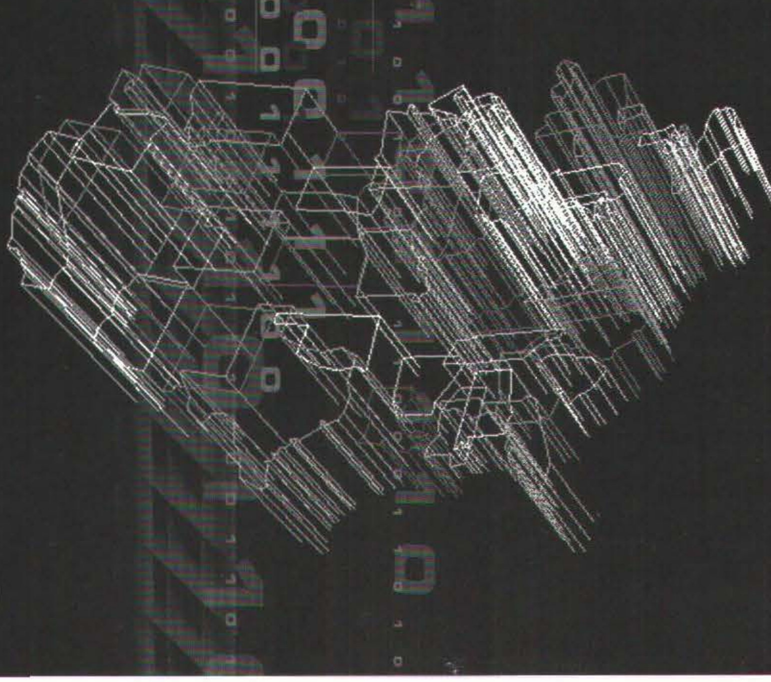

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in this issue

messages

MESSAGE FROM NACIS' PRESIDENT

It is a pleasure to serve as the 1997-98 president of NACIS. No, really, I am serious! (as Dave Barry would say). After well over a decade of association with the organization, serving now and then as a member of the board of directors or the *CP* editorial board, I finally have the pleasure of serving as NACIS' vice president and now president. The words "pleasure" and "president" are seldom found together in the same sentence; let me tell you why I use them together.

For one thing, I get to deliver some good news to NACIS members and others with links to cartography: we have a new editor for *Cartographic Perspectives*. After a two-year search and several guest editors, we found our new editor, Dr. Michael Peterson of the University of Nebraska-Omaha, right at the head of our own editorial

(continued on page 61)

NEW NACIS WEB SITE
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cartographic perspectives

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North American Cartographic Information Society

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about the cover

About the Cover:

The cover was designed by James Swanson using Adobe Photoshop on a Power Macintosh. James is currently finishing his master's degree at the University of Nebraska at Omaha. His thesis concerns the cartographic applications of the Virtual Reality Modeling Language (VRML). VRML is the Internet standard for the description of interactive 3D objects and scenes.

Across the top of the cover, a series of prism maps show the change in US income per capita from 1948 to 1970. In the lower-right is a wire-frame of the extruded states from the VRML map. The stripe down the middle of the page represents a binary data stream with ones and zeroes. Towards the bottom left is a portion of the source code for the VRML map. This VRML ***'world' can be accessed at***

http://osprey.itd.sterling.com/vrml.

essay

That Interactive Thing You Do

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The incorporation of interaction in the display of maps may be viewed as a major accomplishment of the computer-era in cartography. Certainly, interaction has pervaded all forms of mapping, whether it is with a database of a geographic information system, a multimedia atlas on a CD-ROM, or street maps on the World Wide Web. A characteristic shared by all of these forms of mapping is the control that the user has over the resultant map.

However, interactivity is not new in cartography. In fact, it may be as old as cartography itself. While we don't know when the first map was made, it was very likely a product of an interaction between two individuals. It may have been much like the "paper-napkin map" of today – the kind of map that is drawn on any piece of scrap paper when words fail as one tries to explain where something is located. A common characteristic of these maps is that the person for whom the map is being made will ask questions that affect how the map is drawn. For example, the person might ask where a particular landmark is located to provide a point of reference. The map becomes a product of interaction when the maker of the map includes the landmark. It is likely that the first map was a product of this type of interaction.

If the first maps were interactive, what does this mean about cartography now? One way to answer this is to view the progression of cartography in three stages. The initial maps were interactive, perhaps drawn in sand with a stick. A major shift occurred long ago as a more stable medium was used and maps were transformed into static objects, first on clay and later on paper. This was an important transition because it made the communication of spatial information possible without the mapmaker having to be present. However, it removed the interactive component. With the help of GIS, multimedia and the web, cartography, now in its third stage, is becoming interactive again.

The first and third stages are both interactive, but differ in how the interaction is achieved – human vs. computer. What do we call the intervening period? In geology, the time period in which we live is commonly referred to as an "interglacial," i.e., the time between major glacial events. In a similar sense, cartography may be seen as having been in an "interinteractive" period – a period when static maps were the norm. The ice is still melting from this period.

The transition to interactive maps is a difficult one for those accustomed to static representations. A "paper-thinking" envelopes us. It is a type of thinking that is difficult to overcome because we have been influenced by static maps for such a long period. It is the way we think maps should be. It is the way we have come to know the world.

We should remember that while we have adapted to static maps, many people have not. A large percentage of the population cannot effectively use these maps. They apparently do not find that the information is presented in a usable form. The one million daily hits on interactive mapping services like MapQuest are an indication that interactive maps are much more accessible to many people. While we might criticize the poor graphic quality of these maps, people seem to use them.

How can interactive maps be made better? A conversation is a good metaphor to use in understanding what interaction means with a map. An important aspect of a good conversation is that each participant responds in some way to what the other has said. A bad conversation is characterized by no response, a response that has nothing to do with the topic of the conversation, or does not relate to the previous point that was made.

An additional and important aspect of a conversation is that each participant is building up a database of what the other has said. The database can be fairly sophisticated at times. For example, I can remember stories that people have told me several years ago (although they have sometimes forgotten that they have already told me these stories - a flaw in their 'who-have-I-told-this-to' database). We have not reached this stage of sophistication in interactive cartography. The system rarely remembers what it has already shown. (The closest we get to this is the short-term caching structure of a World Wide Web browser.)

Viewed in the perspective of a conversation, the type of interaction that we have with maps on the computer is simplistic. It is somewhat like talking to a person for the first time over and over again. There is no database of the interaction. The computer doesn't remember anything. Because it doesn't remember, it cannot raise the sophistication of the interaction.

Perhaps the conversational form of interaction with maps is not we want. Imagine if the computer responded with messages like:

- I've made this map for you before!
- Don't you remember where that feature is located!
- Can we move to a more intelligent level of interaction, please?

We apparently prefer a more shallow form of interaction with the computer. Perhaps we want to maintain the status of a master. We certainly don't want the computer to challenge us as another person might do.

Some computer games incorporate varying levels of sophistication. They adapt to a particular user and move them forward to more complicated tasks with rewards along the way. This, and the very high level of interaction that characterizes these games, maintain the interest of the user. The user is made to feel part of the game. The interactive map can create the same feeling on the part of the user.

How far we have come from that first interactive map? It might be said that with all of our computers and technology, we still cannot simulate the interaction in a "paper-napkin" map. We may be making more accurate maps and maps that are the result of greater analytical thought, but they may not be as interactive as that first map in the sand.

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XVIII
ANNUAL MEETING

NORTH AMERICAN CARTOGRAPHIC INFORMATION SOCIETY

OCTOBER 7-10, 1998

MILWAUKEE, WISCONSIN

The NACIS Program Committee invites you to participate in this meeting by presenting a paper, poster or exhibit. Plan to organize a session, panel discussion, or workshop. A full range of computing facilities at the University of Wisconsin-Milwaukee will be available for workshops. We look forward to featuring the current challenges confronting map librarians and cartographers.

Potential topics include:

- → *handling digital map-library data*
- → *compiling metadata*
- → *managing the practical constraints of budgets*
- → *exploring data using visualization & virtual reality*
- → *integrating diverse data sources for map production*
- → *marketing cartography services*
- → *developing educational materials*

We also encourage presentations that will complement the symposium *Maps and Minds: A History of Cartography in Geography Education*, which has been organized by the Hermon Dunlap Smith Center for the History of Cartography, Newberry Library. This symposium is co-sponsored by NACIS and will be held in Milwaukee on Wednesday, October 7. To continue themes from the symposium at NACIS, we welcome presentations on maps in education and on cartographic education from historical, current and speculative perspectives. Challenges that reflect the practical side of this topic include production of maps for educational media and collaboration with authors. Topics on maps and society will also mesh with the symposium themes.

Email your 250-word abstract or proposal to the program chair, Cynthia Brewer, by May 1. List names and affiliations of all authors, and include phone and email for the presenting author. We encourage student participation.

Email proposals and abstracts to:
cbrewer@essc.psu.edu
The deadline is May 1 (Space may still be available after the deadline).

Participants will be notified by June 15, 1998, of acceptance of their abstract or proposal.

Beyond Graduated Circles: Varied Point Symbols for Representing Quantitative Data on Maps

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Graduated point symbols are viewed as an appropriate choice for many thematic maps of data associated with point locations. Areal quantitative data, reported by such enumeration units as countries, are frequently presented with choropleth maps but are also well suited to point symbol representations. Our objective is to provide an ordered set of examples of the many point-symbol forms used on maps by showing symbols with linear, areal, and volumetric scaling on repeated small maps of the same data set. Bivariate point symbols are also demonstrated with emphasis on the distinction between symbols appropriate for comparison (separate symbols) and those appropriate for proportional relationships (segmented symbols). In this paper, the variety of point symbol use is described, organized, and encourage, as is research on these varied symbols and their multivariate forms.

INTRODUCTION

Much cartographic research has been conducted on apparent-value scaling and perceptions of graduated point symbols. However, discussion of practical subjective elements of point symbol design and construction is limited, especially for the wide variety of point symbols for representing multivariate relationships that are now feasible with modern computing and output. The primary purpose of the paper is to suggest innovative graduated symbol designs and to examine useful combinations for comparing variables and representing proportional relationships. This paper was inspired by the bivariate symbol designs of hundreds of students that have taken introductory cartography courses with Cindy Brewer (at San Diego State and Penn State). These students have been creative and thoughtful in the many ways they have found to represent multivariate map data, with few choosing the old standby of graduated circles when given the flexible design capabilities of the illustration software.

". . . graduated point symbols were the most common quantitative symbolization choice."

Although thematic atlases have long made use of a wide variety of point symbols, cartography textbooks emphasize use of graduated circles. Mersey (1996) surveyed the qualitative and quantitative point symbols used in eight recently published atlases and found that graduated point symbols were the most common quantitative symbolization choice (36 percent; with 59 percent of 36 being circles or sectored circles). In comparison, choropleth maps were used for 24 percent of the quantitative representations. Mersey notes that, despite the prevalence of point symbol mapping, choropleth maps are the mainstay of most microcomputer-based GIS programs. All of the 13 she reviewed offered choropleth mapping, with four of the 13 not able to produce graduated symbol representations. Muehrcke (1996), citing Abler (1987), refers to choropleth mapping as "a cartographic abomination that GIS will swiftly kill off" (p. 272) and then bemoans its continued use. Although GIS has enabled production of more sophisticated representations, it has also made it easier (for far more people) to produce choropleth maps as well.

Cartograms and dasymetric mapping offer alternatives to choropleth mapping, but here the more popular point symbol representations will be examined. Point symbols are appropriate for quantitative data at point locations and for areal units. They are not affected by the physical size of enumeration units (large units produce large symbols on choropleth maps) and can be used to illustrate a spatial distribution while maintaining recognizable geographic boundaries (unlike contiguous cartograms). Widely spaced point symbols in regions of large enumeration units (such as counties of the western U.S.) produce the appropriate sense of sparse data and they contrast well with dense clusters of symbols in areas of small units (such as eastern U.S. counties). Thus, point symbols preserve the spatial structure of the entire map without the problems associated with choropleth maps or cartograms.

The paper begins with a review of literature on graduated symbols to update the reader on this long research tradition in cartography and psychology. The remainder of the paper is devoted to a description of the variety of symbol designs possible and the nuances in symbol designs that make them appropriate for different types of bivariate map data. A wide variety of symbols are illustrated with the hope that these examples will inspire and encourage the authors of maps and GIS displays to produce a wider variety of engaging and enlightening data displays well-suited to communicating and exploring their geographic information.

LITERATURE REVIEW

Psychophysical Study of Graduated Circles

Apparent-value scaling and graduated circles have received a great deal of attention from cartographic researchers. The circle was, and still is, the most widely used graduated point symbol. Flannery's 1956 and 1971 work firmly established apparent-value scaling as a topic of research and discussion for the cartographic community.

Cox (1976) concluded that apparent value scaling "... turned out to be inadequate as a remedy for the underestimation of symbol size ratios" (p. 73). His research examined legend construction and anchor effects associated with circle and square size estimation. He found that using a legend containing a small, mid-size, and large symbol (relative to the mapped data) led to the most accurate estimates. His findings supported Dobson (1974), who stated "a review of psychophysical research on proportional circle symbols indicates that readers can interpolate between circle sizes but that extrapolation is quite difficult" (p. 53). Chang (1977) confirmed Cox's findings with the results of a similar study comparing size estimation using ratio and magnitude estimation methods.

"Apparent-value scaling and graduated circles have received a great deal of attention from cartographic researchers."

Macmillan et al. (1974), Teghtsoonian (1965), Maddock and Crassini (1980), and Shortridge and Welch (1980) examined the effects of the specific wording of the request that subjects estimate circle magnitudes. The latter three experiments were not entirely applicable to cartography because the standard for comparison needed to be remembered when estimations were made; whereas normally the "standard" would be simultaneously available in a map legend. Macmillan et al. tested the use of instructions to subjects with a standard present during estimations. They found that instructions for use of a fitting strategy improved the accuracy of subjects' size judgments.

By the mid-1980s, authors became increasingly skeptical about the usefulness of apparent-value scaling and shifted research away from correction by exponent. Griffin (1985) was particularly critical of its usefulness, stating:

> Perceptual rescaling may have merits for particular types of map user, or for the generation of immediate visual impressions, though both cases remain to be proven. Such rescaling places increased demands on

map space and, in the experimental context, promotes an increase in the variability of subject responses. (p. 35)

In analyzing intra- versus inter-subject variation in circle size estimation, Griffin pointed out the ineffectiveness of apparent-value scaling for increasing the estimation accuracy of subjects who performed poorly. He also noted that apparent-value scaling impaired those subjects whose estimates were most accurate. In contrast to Griffin's results, Olson's (1975) earlier work with circle-size and dot-density estimation examined the interaction between apparent-value scaling and training in the form of practice and feedback about correct answers (for commentary see Williams, 1977, and Olson, 1978). She concluded that the combination improves both the accuracy and dispersion of subject estimates, unlike results for either scaling or training alone. Assuming that a map legend functions as training in a limited way by providing example sizes with associated data values, apparent-value scaling may produce improvement in graduated-circle estimation for complete map-reading contexts that is not seen in simpler experimental contexts.

Interactive and animated mapping facilitates examination of multiple symbol scalings. Slocum and Yoder (1996) described student use of Visual Basic to animate series of graduated-circle maps. One approach was to permit interactive selection of scaling values from square-root areal scaling to linear scaling of diameters, which enhanced spatial pattern by greatly exaggerating relative circle areas.

Heino (1991) noted that graded rather than graduated symbols may be the best method of displaying quantitative data on a map. Heino argued that since graduated point symbols were meant as visual abstractions, graded symbols sufficiently convey the intended message without creating the problems associated with graduated symbol perception. Dent (1996) also discussed range-graded circles in his textbook. His discussion included Meihoefer's (1969) ten circle sizes that were "consistently discriminated by his subjects" (Dent, p. 174) as well as his own untested set of graded circles. Similarly, Monmonier (1977) recommended a regression-based method of circle scaling intended to improve visual correlations between maps by essentially imposing a shared minimum and maximum circle size on the data representations of two (or more) maps to be compared. His approach to scaling permitted accurate value estimations from legend examples, but correct size ratios between symbols were not maintained.

This shift in research away from apparent scaling was supported by authors such as Worth (1989) who discussed, as Flannery had, some of the problems with approaching cartographic research as a pure science. He noted that much cartographic research borrows from psychology because both fields are highly subjective, and stated that, "By their very nature, experimental tests in cartography must involve many subjective decisions, and although we must do our best to apply the scientific method, subjectivity will always be involved" (p. 152).

". . . much psychophysical study eliminates spatial structure from our perception of thematic figures . . ."

Petchenik (1983) offered an in-depth discussion of cartographic research and the problems associated with limiting ourselves to psychophysical study. She explained that much psychophysical study eliminates spatial structure from our perception of thematic figures, and quoted Chang (1980) who stated, "The stimulus-response relationship for circles is fairly complex, and any correction in map design based on one psychophysical study alone is of limited value, especially given the incomparability between the conditions of the experiment and of real map use" (p. 161). There have been calls for more cognitive research to counter the limitations of psychophysical research in cartography (Olson 1979; Fraczek 1984), and Gilmartin (1981a) discussed the inextricable link between cognitive and psychophysical study. Peterson (1985, 1987) examined mental images of maps and comparison of pattterns on point symbol maps, rather than comparison of symbols. MacEachren's *How Maps Work* (1995) is a current, in-depth analysis of human cognitive processes used to understand map symbols and map patterns.

Beyond Circle Size Estimation

Groop and Cole (1978) studied the relative effectiveness of cut-out versus overlapping graduated circles, since many graduated circle maps include dense clusters of circles. Their analysis showed that estimation errors associated with cut-out circles were significantly greater than those associated with overlapping circles. Cut-out circles are seldom used today because of the ease of constructing overlapping circles with the computer. However, Dent (1996) noted that they "add a three-dimensional (plastic) quality to the map" (p. 177). Groop and Cole also questioned the effects of clustering on the accuracy of size estimation. Gilmartin (1981b) found that circle size estimation was affected by neighboring circles and that the effect can be minimized by including intervening linework such as boundaries separating enumeration units. Dent noted the current lack of a solution to this problem.

Researchers have examined the effects of both lightness and hue on symbol-size estimation. Meihoefer (1973) studied the effect of transparent, gray, and black circles on size estimation with his 1969 set of graded circles. He found no difference in subject perception with these three fill variations. Crawford (1971) concluded that the perception of circle size was the same whether the circles were represented in black or gray. Patton and Slocum (1985) conducted a study to assess the effect that aesthetic use of color had on pattern recall of graduated circles. Lindenberg (1986) examined the effect of color on size estimation for graduated circles. Neither Patton and Slocum nor Lindenberg found differences associated with color, substantiating Meihoefer's and Crawford's studies. In contrast, Williams (1956) found small differences in size estimates between colored symbols (circles, squares, triangles) and black symbols of the same size, with the largest difference of six percent between equivalent yellow and black symbols.

Griffin (1990) recognized the increase in cognitive study of graduated symbol use, but suggested continued research using the stimulus-response approach. He investigated visual contrast between graduated circles and their map background, user preference for opaque versus transparent circles, and the effect of varying circle fill color on size estimation. His subjects disliked a white fill most and showed a strong preference for black figures. Preference results for opacity depended on a subject's preference for clarity of the figure or detail of the background. As in Crawford (1971), Meihoefer (1973), Patton and Slocum (1985), and Lindenberg (1986), color variation was shown to have no effect on size estimation.

". . . color variation was shown to have no effect on size estimation."

Comparisons of Types of Graduated Symbols

Unfortunately, little has been written by cartographers comparing the relative usefulness of different types of graduated point symbols. This lack stems, in part, from the historical difficulty of manually constructing graduated symbols. Graduated circles were versatile and easy to construct through both manual and automated means, and have, therefore, received greater attention. In addition, few researchers have investigated the representation of comparison and proportional relationships within multivariate graduated symbols.

In 1926, Eells examined "The Relative Merits of Circles and Bars for Representing Component Parts." He noted commonly held criticisms of using circles to illustrate component parts (what we refer to as proportional relationships) including: difficulty in rapid and accurate estimation of values, inaccuracy of estimation due to their areal nature, and the suggestion that "while their popularity and psychological appeal are grudgingly admitted their use is 'an insult to man's intelligence' " (p. 122). However, Eells' study concluded that circle diagrams divided into component parts were easily and accurately read, that accuracy increased with the number of subdivisions of circles but decreased for subdivided bars, and that the use of circle diagrams was "worthy of encouragement" (p. 132). Croxton and Stryker's 1927 follow-up study supported Eells's findings and suggested that for illustrating 25, 50, and 75 percent relationships, circles worked significantly better than bars. Croxton and Stein (1932) further examined the accuracy of size estimates using bars, squares, circles, and cubes. They concluded that scaled bars yielded more accurate results compared to area or volume symbols. Furthermore, they found that performance with both circles and squares was better than with cubes. Their study supported the commonly held belief that the fewer dimensions a graduated symbol possesses, the more accurately its size is estimated (a general rule strongly supported by Cleveland, 1985, p. 254). Neither Croxton's studies nor Eells' study was performed in a cartographic context. Their results offered basic comparisons of graduated symbols without the complications of spatially registered data.

"while their popularity and psychological appeal are grudgingly admitted their use is 'an insult to man's intelligence'"

Clarke (1959) examined the relative accuracy of size estimation for lines, circles, squares, spheres, and cubes. His data were collected using three symbol sizes in each trial. Subjects were asked to estimate the sizes of the small and large symbols using a middle-size symbol. Greater errors in estimations of size occurred as the number of dimensions increased and as the difference between the symbol and the standard increased. Ekman and Junge (1961) elaborated on this conclusion by generating power functions for symbol types.

Flannery (1971) included examination of the relative effectiveness of wedges and bars compared to circles in his research. Although he concluded that wedges were not estimated as accurately as circles, he noted their usefulness for showing proportions for specific locations (cities, ports, and intersections, for example) because the vertex naturally points to the place to which the value belongs. He also noted the relatively high accuracy of estimations with linearly scaled bars.

Crawford (1973) examined perceptions of graduated squares. Specifically, he studied the potential for linear rather than areal estimation of square size and whether squares were correctly, under-, or over-estimated. His regression model clearly indicated that square sizes were estimated areally, not linearly, and he showed that square sizes were more accurately estimated than circles. Likewise, Heino (1991) recommended the use of squares and cubes, instead of circles and spheres, for accurate estimation of data sets with large ranges.

In addition to comparing types of symbols, multivariate symbols would seem a logical topic of research in thematic cartography. Both MacEachren (1995) and Nelson and Gilmartin (1996), however, note that very little of this research has been done. One theme in their reviews of the topic is the link between the design of multivariate symbols and whether symbol dimensions representing each variable remain *separable* or are combined in a more holistic symbol with *integral* dimensions (Shortridge 1982). Nelson and Gilmartin examine symbols representing sets of four variables with attention to the multiple purposes of multivariate map symbols: from 'what' and 'how much' at the local level (which may be better represented with separable dimensions) to regional patterns and correlations between variables (which may be better represented with integral dimensions).

As an example of multivariate symbol research, Slocum (1981) examined two-sectored pie graphs. Specifically, he measured the just-noticeable difference for sector size and accuracy of sector size estimation. He found that subjects could not discriminate between sector size differences of less than nine degrees, and that sector sizes were estimated within a three-percent margin of error. He suggested rounding data to the nearest five percent, rather than one percent, before drawing sectors. His study was, in part, a response to Balogun (1978), who suggested the use of decagraphs (ten-sided polygons) for representing proportions. Examples of decagraph use can be found in the *Atlas of Newfoundland and Labrador*, where they are used to represent economic data (McManus et al. 1991, plates 10 and 19).

Point Symbol Discussion in Cartographic Textbooks

Cartography: Thematic Map Design by Dent (1996) and *Elements of Cartography* by Robinson et al. (1995) are two widely used collegiate texts. Chapter 8 of Dent's book offers a concise survey of the research that has been conducted over the past twenty-five years, including apparent scaling (Flannery 1971), effects of symbol clustering on size perception (Gilmartin 1981b), anchor effects (Cox 1976), range grading (Meihoefer 1969), and open and cut-out circles (Groop and Cole 1978). Dent also directs attention to multivariate graduated point symbols, the use of graduated squares and triangles, and the use of volumetric symbols. Robinson et al. briefly discuss the use of variations in symbol shape and orientation to represent classes of graded data. They offer an in-depth discussion of graduated circle use in representing univariate data with the addition of a color sequence for a second map variable. Their coverage of multivariate mapping is divided into four types, in their words: superimposition of features (different symbols), segmented symbols (sectored pie graphs), cross-variable mapping (bivariate choropleth), and composite indexes (cartographic modeling). They warn students that "supermaps" illustrating too many variables often hinder the clear communication intended by the mapmaker.

Issues for Future Research

Point symbol maps may be designed with multiple objectives, such as encourging accurate symbol-size estimation, easing legend matching, attracting attention, representing patterns across a map, and showing spatial relationships between variables. Success for one design objective often necessitates failure for competing objectives (Petchenik 1983), though interactive environments that encourage multiple representations improve on this discouraging reality. Further experimental testing and other investigations should be structured to account for the multiple tasks for which maps are designed.

"Further experimental testing and other investigations should be structured to account for the multiple tasks for which maps are designed."

Examples of competing objectives can be found for varied aspects of point symbol mapping, such as range grading, symbol dimensionality, map comparison, and multivariate symbols. The literature reveals a tension between accurate estimation of individual symbols and the alternative of range-graded symbols, for which data values are classed and assigned to ordered but arbitrarily scaled symbol sizes. Range-graded symbols are selected to be obviously different in size and easily identified in a legend. A hybrid approach with symbols scaled to means of data classes, for example, may be a useful compromise between the comfort of easy identification and an accurate overview of relative magnitudes across a map. Similarly, low symbol dimensionality improves symbol-size estimation but may hinder map pattern interpretation. The larger range in sizes of linearly-scaled symbols (bars, for example) causes symbols to extend farther across the map than higher-dimension and more compact symbol forms (areal and volumetric symbols such as squares or cubes) representing the same data. Adjustments within a map series, such as equalizing symbol areas among maps before comparison (Peterson 1985) or using constant symbol sizes for minimum and maximum data values (Monmonier 1977), assist pattern comparison but interfere with comparison of data magnitudes between maps. Another challenge is choice of multivariate mappings with separable symbol dimensions (which may encourage comparisons within symbols and within variables) versus integral dimensions (which may improve understanding of patterns in correlations between variables). Although researching the endless variety of multivariate point symbols is a daunting prospect, it would be useful to see work on how people use and understand these types of representations.

"A hybrid approach with symbols scaled to means of data classes, for example, may be a useful compromise . . ."

The next sections summarize many possibilities for point symbol mapping. In addition to the theoretical research issues that are reviewed, interest in these symbols also invites practical research on how point symbols can be effectively implemented in mapping, GIS, and visualization software environments.

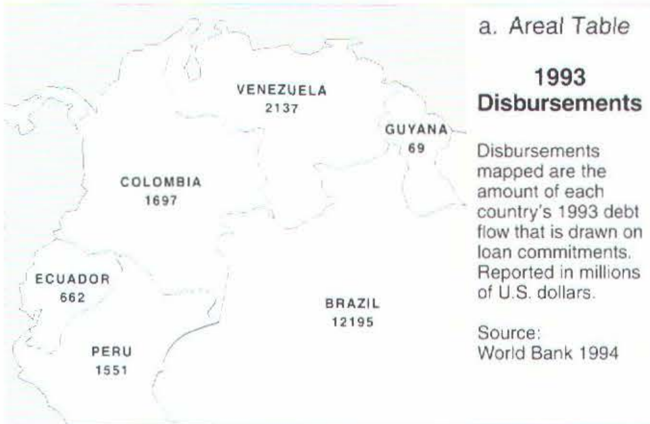
GRADUATED POINT SYMBOL EXAMPLES AND SOURCES OF INNOVATION

Figures 2 through 8 illustrate both common and innovative ways to illustrate quantitative univariate and bivariate data with graduated point symbols, and Figure 1b presents a choropleth version of the map for comparison. In addition to univariate representations, this discussion concentrates on basic ways of representing proportional and comparison relationships on bivariate maps. These terms require some explanation. 'Proportional' data refers to relationships in which one data set is part of the other data set being mapped. Similarly, Eells (1926) referred to representing proportional relationships as illustrating component parts. 'Comparison' data refers to those data that are two separate measures but the relationship between them (correlation) is of interest. One data set is not a part of the other. The data on loan disbursements that was used for the maps in this paper, for example, may be divided into public and private *proportions* or it may be *compared* to principal repayments for the same year.

Our mapped data (Table 1) were taken from a World Bank report (1994). The same data are mapped in each of the figures to aid comparison of the symbol types, though the small extent of the maps does not foster regional comparisons and does not allow evaluation of the symbols with more numerous enumeration units. All data are for countries in northern South America. Point symbols are used for country data in these maps to emphasize that *point* symbols are appropriate for *areal* data, even though some authors restrict their representations to choropleth mapping (Figure 1b). All data are for 1993 debt levels: total loan disbursements, principal repayments, and the proportions of total disbursements for public versus private loans. Table 1 notes provide further explanation of the variables.

Univariate Data: Total 1993 Disbursements

Figures 1 through 4 illustrate a variety of methods for mapping univariate data. Figure 1a lists disbursement values as an areal table. Figure 1b is a choropleth map of these data, which is shown for compari-



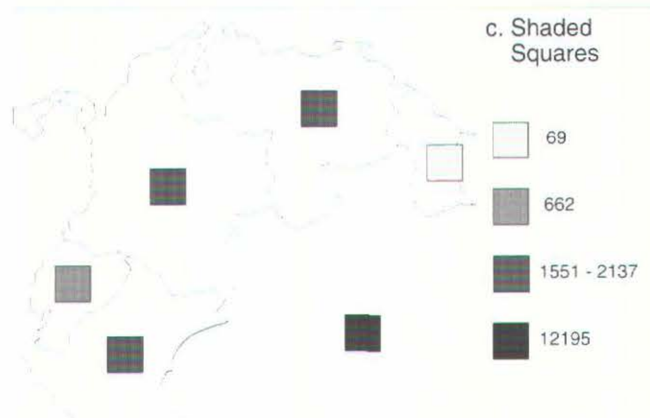


Figure 1. Areal table (a), choropleth (b), and shaded square (c) representations of loan disbursement data. The many point symbols described in this paper are alternatives to the flawed representations in a and b. Numbers (a) do not provide a visual representation of relative magnitudes of data values. The sizes of the gray fills of the choropleth map (b) are controlled by the sizes of the countries rather than the data values. Country size has a large visual impact on the data representation but it is not directly related to the economic variable of interest. For this reason, cartographers generally admonish against representing total values with a choropleth map. Shaded point symbols of a constant size, such as squares (c), are one way of removing the effect of enumeration-unit size on a gray-scale symbolization.

Country	Loan Disbursements[a]	Principal Repayments[b]	Disbursements to Public Entities[c]
Brazil	12195	6212	3265
Colombia	1697	2083	1547
Ecuador	662	488	497
Guyana	69	46	69
Peru	1551	1007	1492
Venezuela	2137	1515	1877

Table 1. Debt Data for Maps in All Figures

Notes:

All data are for 1993 and are reported in millions of U.S. dollars. The data source is a 1994 World Bank publication titled *World Debt Tables, External Finance for Developing Countries, Volume 2*.

[a] Loan disbursements are defined as "drawings on loan commitments during the year specified" (p. *xv*). Figures 1 through 4 show univariate maps of disbursements.

[b] Principal repayments are "the amounts of principal (amortization) paid in foreign currency, goods, or services in the year specified" (p. *xv*). Principal repayments are compared to loan disbursements in Figures 6 and 7a.

[c] Disbursements to public entities are external obligations of public debtors, "including the national government, a political subdivision (or an agency of either), and autonomous public bodies" (p. *xv*). The remainder of loans are to private debtors who are not guaranteed by public entities. Public and private disbursements are the proportions of total disbursements mapped in Figures 7b and 8.

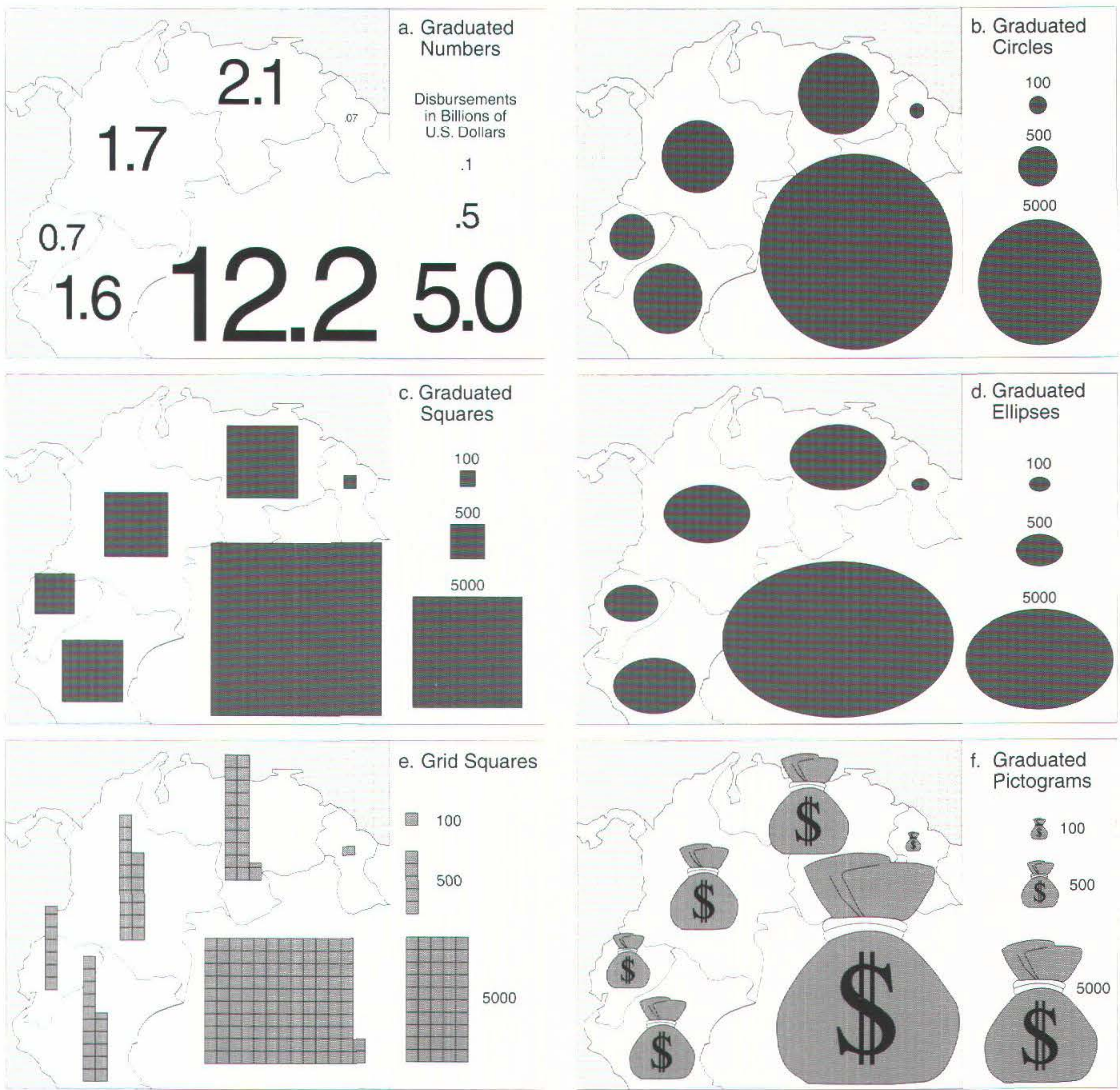


Figure 2. Areal univariate point symbols representing 1993 loan disbursement data: graduated numbers (a), graduated circles (b), graduated squares (c), graduated ellipses (d), grid squares (e), and graduated pictograms (f). Data values are in millions of U.S. dollars, except for Figure 2a which shows billions of U.S. dollars (see Table 1 for description of mapped data). Symbols are sized to data values using square-root

son but is not a recommended representation for these total dollar values. Figure 1c is a variation on the gray-scale representation of the choropleth map, with the gray fills applied to a repeated square symbol of constant size. This variation removes the unwanted effects of variation in enumeration-unit size, though differences in lightness are more difficult to compare than differences in symbol area (Cleveland 1985, p. 254). Pazner (1997) proposed a similar representation with constant-size squares that he termed "tile maps." Size and lightness may also be used as redundant symbolizations (each representing the same data values within symbols), and lightness may be used to map a second variable within a graduated

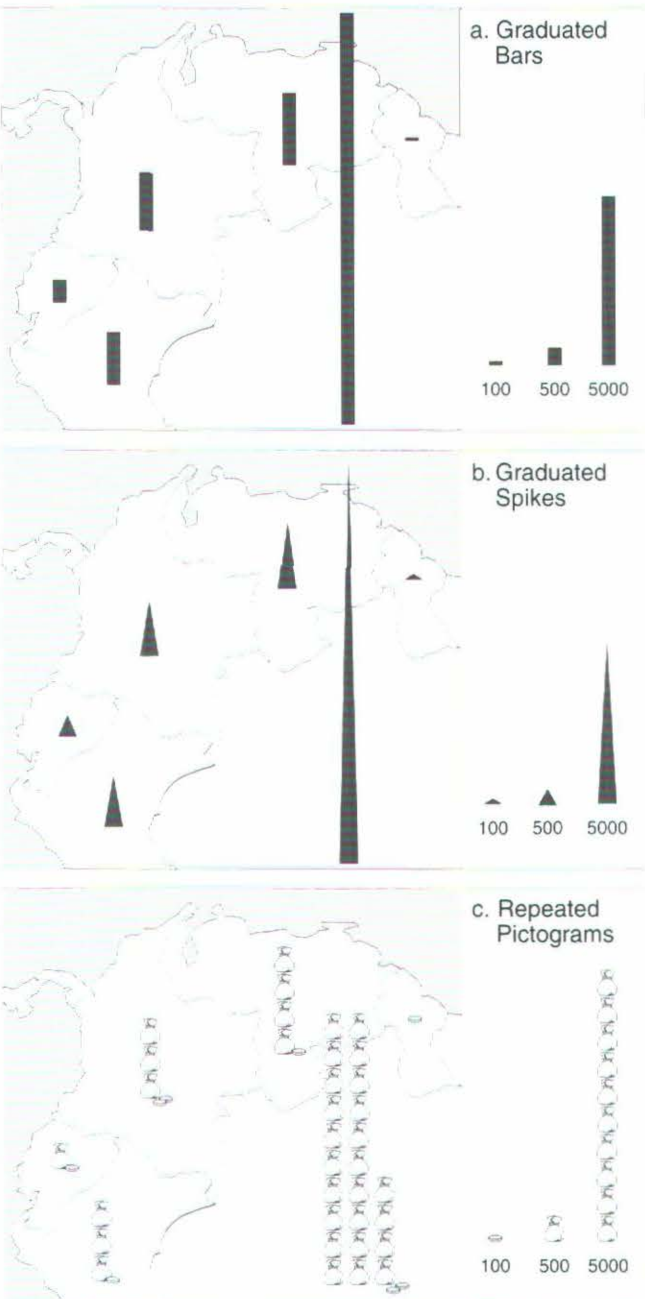


Figure 3. Linear univariate point symbols representing 1993 loan disbursement data: graduated bars (a); graduated spikes, formed by triangles with a constant base and heights linearly scaled to data (b); and stacks of repeated pictograms (c).

symbol. These valid variations are not pursued because this paper has been limited to a manageable set of possibilities by focusing primarily on graduated symbol forms.

Like Figure 1a, Figure 2a is an areal table with the sizes of numbers graduated by their values. Graduated numbers offer the reader the accuracy of a table with the advantage of a visual representation of relative magnitudes. (Note that Figure 2a is the only map with symbols that represent debt in billions of dollars; Figure 1a and all other map legends list debt in millions of dollars.)

"Graduated numbers offer the reader the accuracy of a table with the advantage of a visual representation of relative magnitudes."

Traditional graduated circles and squares also work well with the disbursements data set (Figure 2b and c). Their familiarity and versatility make them mapping options that should not be overlooked. By sizing the height and width of the entire set of symbols by a constant ratio, graduated ellipses (Figure 2d) offer a mapping solution for sets of enumeration

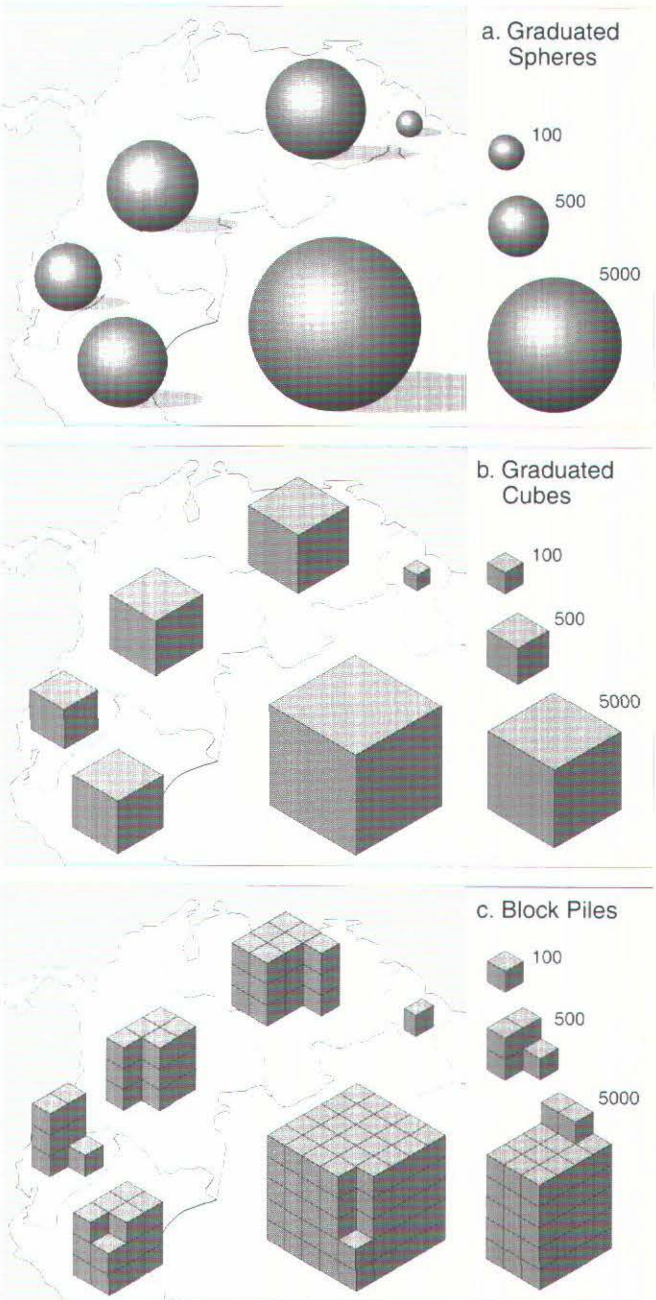


Figure 4. Volumetric univariate point symbols representing 1993 loan disbursement data: graduated spheres (a), graduated cubes (b), and block piles (c). Cube-root scaling is used to size the spheres and cubes, and block piles are constructed by repeating the smallest cube symbol.

units having generally elongated shapes. These ellipses are also included for comparison to a later bivariate use (Figure 6g). Magnitudes represented with a square grid (Figure 2e) may aid accurate interpretation because individual cells can be counted.

Another areal symbol, the 'money bag' pictogram (Figure 2f) offers an example shape that more literally reflects the data, captures the reader's attention, and may be scaled to represent relative quantities. Pictograms are particularly well suited when 'catching' the reader's eye is a priority, making them common in magazines, newspapers, and educational material. *The New State of the World Atlas* (Kidron and Segal 1984) offers good examples of the unlimited possibilities of pictogram use. This atlas and later editions (for example, the fifth edition was published in 1995) use graded pictograms to cleverly illustrate everything from radio receivers per 1000 people to worker exploitation rates. An example similar to that used in Figure 2f can be found in the *Atlas of Newfoundland and Labrador* (McManus et al. 1991, pl. 19). Although pictograms may not be well-suited for accurate magnitude estimation, variety and ability to match the theme of the data being mapped make them a worthwhile consideration.

Linearly-scaled symbols (Figure 3) work well for these data because of the relatively large enumeration units. The bars in Figure 3a overlap multiple enumeration units and may be difficult to associate with the correct location. In contrast, the larger bases of the spikes in Figure 3b better associate the symbols with their enumeration units. Stacks of repeated pictograms (Figure 3c) offer a linearly-scaled version of pictograms (a similar pictogram is areally scaled in Figure 2f). Alternatively, scaling the height of a single tall pictogram for each enumeration unit is also appropriate. For mapping phenomena such as mercury in sediments, makers of *The National Atlas of Sweden: The Environment* (Bernes and Grundsten 1992) use linearly-scaled graduated columns set on an oblique perspective projection of Sweden viewed from the east. This technique produces an interesting map and allows the uncluttered use of linearly scaled bars that would be stacked atop one another in a more traditional planimetric view oriented to the north.

Finally, volumetric symbols such as cubes and spheres (Figures 4a and b) are used for data with an extreme range and are relatively easy to construct. Spheres can be rendered using a circle with a radial fill and a shadow (Figure 4a). Cube construction is more challenging because of projection options (Mackay 1953; Ekman et al.

1961; Brewer 1982; Dubery and Willats 1983; Figure 5). Block piles (Figure 4c) have long been associated with Raisz's talent for cartographic symbolization (1939, 1948).

Comparison Data: Disbursements and Principal Repayments

The possibilities for comparing data with point symbols on bivariate maps are limitless. The focus will be on several combinations of circles and squares, as well as bars, ellipses, and cubes. The large number of arrangement options available using common graduated circles and squares (side by side or overlayed) offer different visual impressions while illustrating the same data (Figure 6a, b, d, and f). Overlapping the symbols produces a more integral symbol that involves pattern recognition because differences in relative values produce different overall symbol forms (compare the mostly black symbol for Colombia, which is the only country for which payments exceed disbursements, to the others). Combining shapes for two qualitatively different variables, such as graduated circles and squares (Figure 6f), increases the variation in overall symbol forms but makes relative sizes difficult to compare.

There are many options beyond combinations of circles and squares for comparing data. Adjacent semicircles (Figure 6c) clearly illustrate differences between the two data sets. However, the adjacent straight edges may lead to linear rather than area-based estimates of value differences. Estimates of differences between pairs of linear symbols are easier to make, although graduated bars (Figure 6e) can be more 'cumbersome' because linear scaling increases the range of the map covered by symbols (square-root scaling for areal symbols and cube-root scaling for volumetric symbols produce more compact shapes). One student (Jeff Erickson) offered a creative combination for pairing graduated cubes (Figure 7a). Cubes may also be placed side by side or stacked. An example of using pictograms to illustrate comparison data can be found in Thomas's *Third World Atlas* (1994). He used a split textbook to illustrate "Gross primary school enrollment ratio" (p. 59) between males and females. The left side of the book was linearly scaled to the percentage of male enrollment; the right side to female enrollment.

Ellipses (Figure 6g) may be constructed with their axes scaled to illustrate different sets of data, in this case disbursement on the horizontal axis and principal repayments on the vertical. MacEachren (1995, p. 90) describes this combination as an integration of attributes merged into one symbol. He cites Garner (1976) when stating "that object integration is more likely to lead to integral or configural conjunction than will two distinct spatially contiguous objects (e.g., paired bars on a bar chart)" (p. 90). The axes of these ellipses were scaled using the linear dimensions of the bars in Figure 6e. When ellipses are highly elongated in one direction or the other, the reader will recognize spatial patterns in variable differences by the orientation of the symbols' major axes. Ellipses with more circular shapes represent comparisons for which neither of the mapped values are significantly larger than the other. Rase (1987) included bivariate ellipses in his point-symbol mapping software.

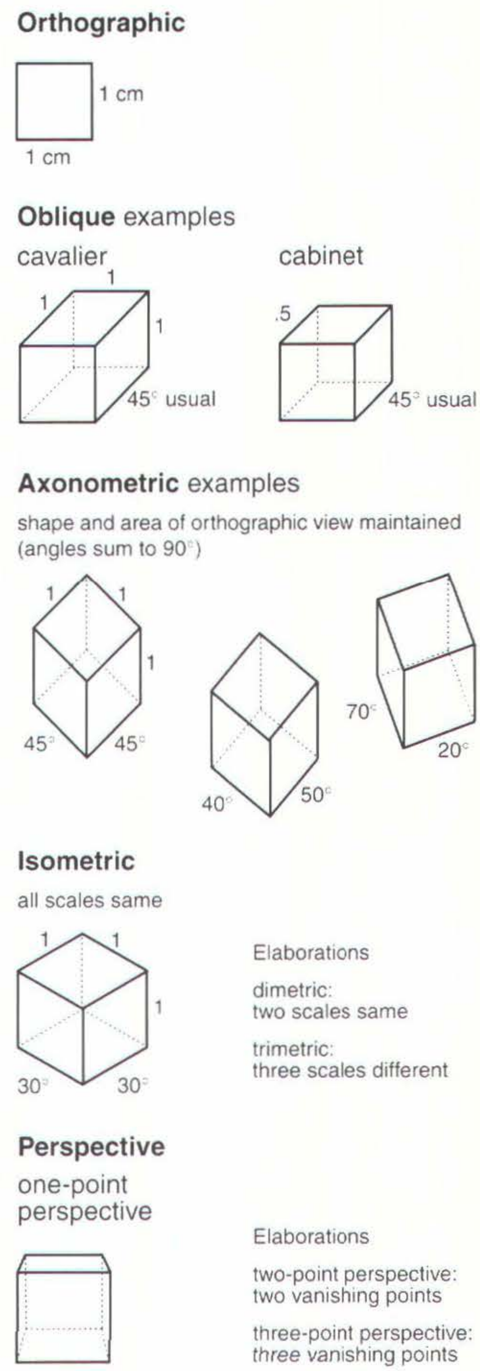
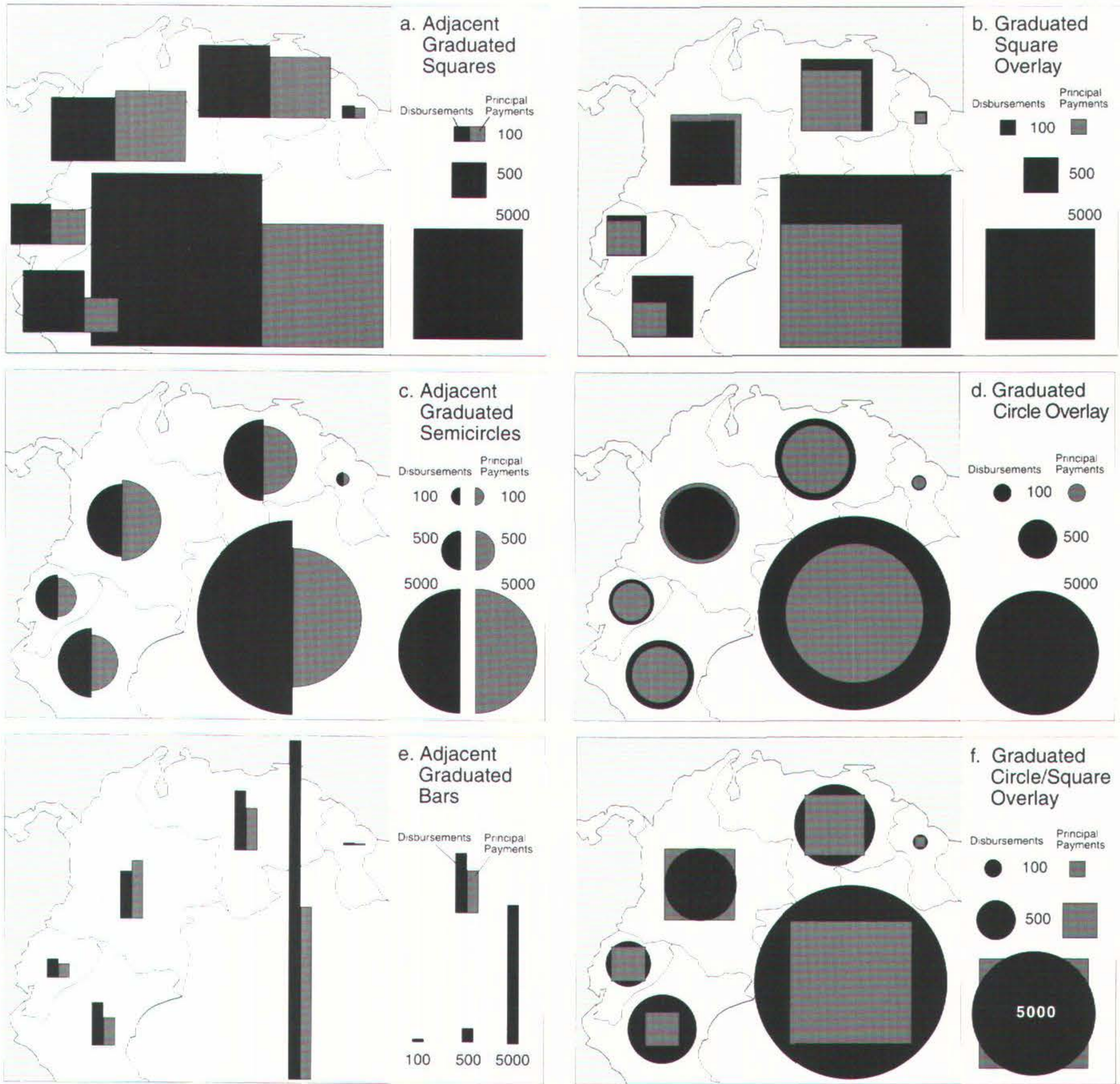


Figure 5. A sampling of the many ways of drawing three-dimensional symbols, using a 1-cm cube to demonstrate the effects of various projection systems (Dubery and Willats 1983). The cube projections generally increase in sophistication from the top down in this figure.



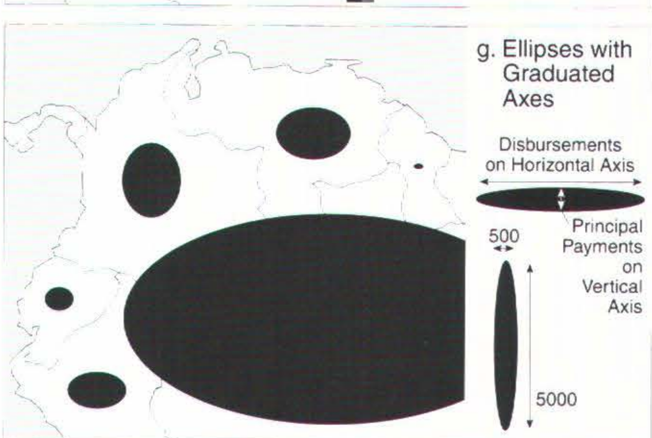


Figure 6. Areal and linear bivariate point symbols for data comparison. Related variables, 1993 disbursements and principal repayments, are compared on each map. Note that payments exceed disbursements for Colombia. Thus, a representation of repayments as a proportion of disbursements (a circle segment for example) would be quite awkward from both practical and logical perspectives. Example comparison symbols are: adjacent graduated squares (a), graduated square overlay (b), adjacent (areally scaled) graduated semicircles (c), graduated circle overlay (d), adjacent graduated bars (e), graduated circle and square overlay (f), and ellipses with graduated axes (g). Ellipse axes in g are linearly scaled to two data values to produce both varied shapes and sizes, though symbol areas are not directly scaled to a mapped variable. The overall look of the overlay symbols (b, d, and f) change markedly depending on which variable is the larger of the two. Overlay symbol construction is awkward where amounts are near equal because symbols are almost the same size but the slightly smaller one will take visual precedence (note Guyana's gray symbol).

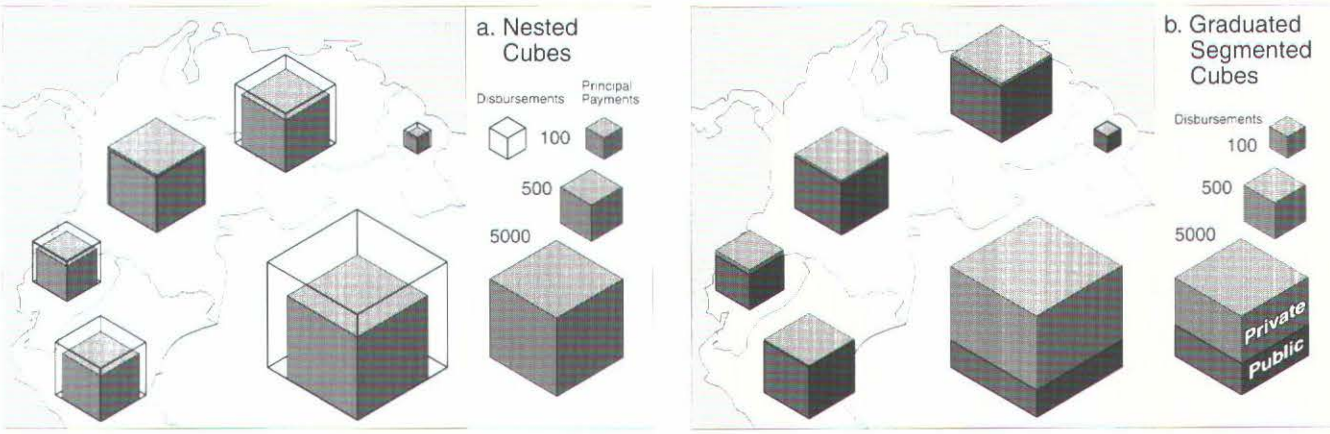


Figure 7. Volumetric bivariate point symbols for both comparison (a) and proportional (b) relationships. The same data represented in Figures 6 and 8 are used for the cubes in 7a and b respectively.

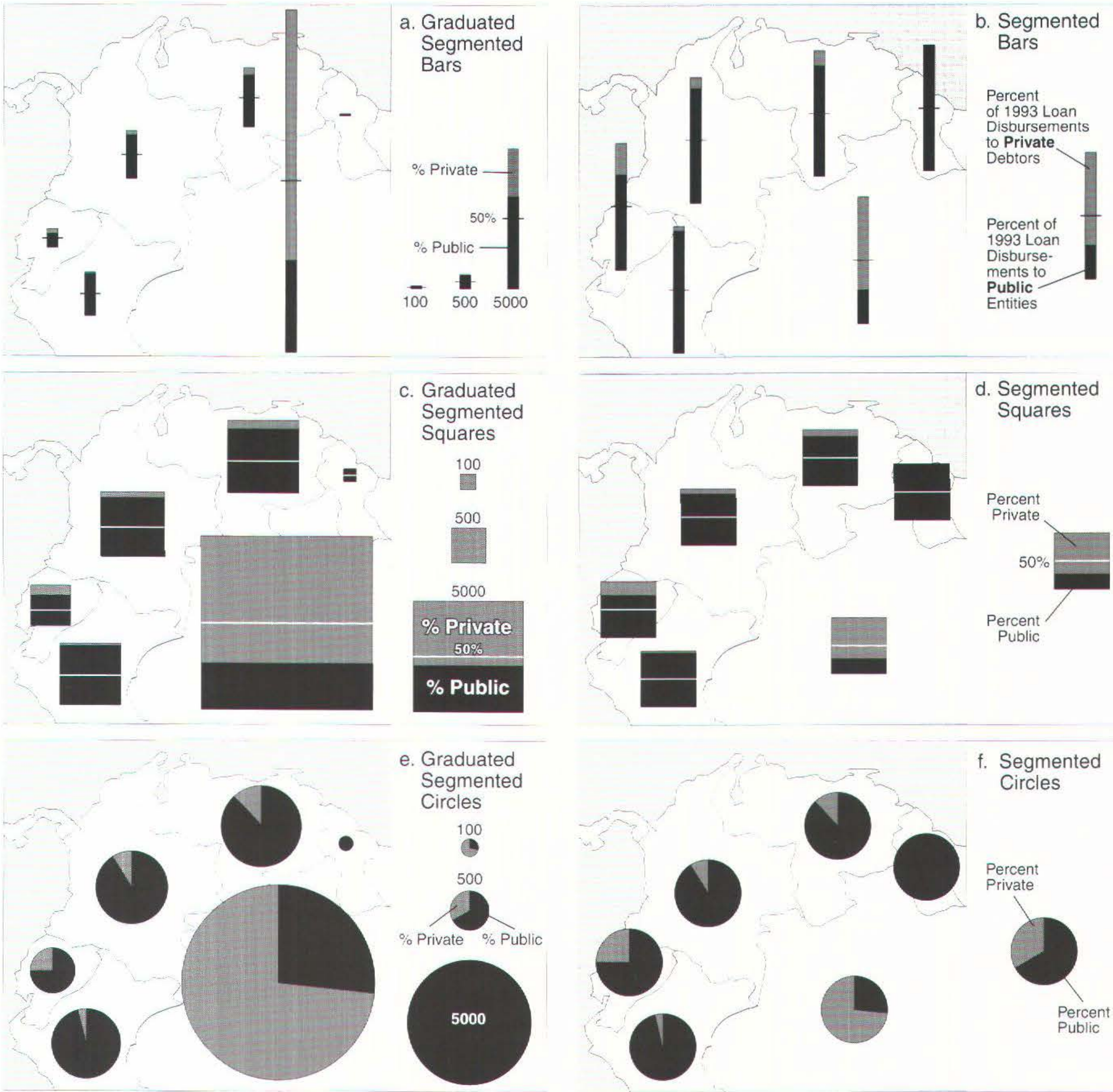
Proportional Data: Public and Private Components of Disbursements

Mapping proportional data differs substantially from mapping comparison data because the smaller of the two data sets is always part of the larger set, unlike the disbursement and repayment data used in the comparison examples (Figure 6 and 7a). In Figures 7b and 8a, c, e, and g, graduated symbols are scaled to represent total disbursements and are segmented by the proportions of loans to public and private entities. Symbols of constant size in Figures 8b, d, and f are segmented to represent only the proportions of the disbursements' compositions, not the total disbursement value (as the graduated symbols do) so they are akin to univariate symbols. In all cases, the black portions of each symbol represent disbursements to public entities and the gray portions to private. For example, the use of graduated segmented circles (Figure 8e) allows the map reader to compare the total value of disbursements among countries as well as the proportions of private and public disbursements. In contrast, maintaining a constant symbol size (Figure 8f) focuses the reader's attention on the proportional relationship.

"In contrast, maintaining a constant symbol size (Figure 8f) focuses the reader's attention on the proportional relationship."

Examples of sectored circles and wedges (Fig 8e, f, and g) are found in a variety of sources including *Historical Atlas of Canada, Vol. III* (Kerr and Holdsworth 1990), *The National Atlas of Sweden: The Environment* (Bernes and Grundsten 1992), and *The Maritime Provinces Atlas* (McCalla 1988). The *Historical Atlas of Canada* makes extensive use of sectored circles, and often uses the space surrounding the map to allow extreme symbol sizing. Wedges, often used in *The National Atlas of Sweden*, are particularly well suited for illustrating quantitative data associated with points like ports or cities (p. 97 for example). Wedges can easily be rotated to fit in where other 'bulky' symbols can not easily be associated with a point location. The graduated wedge radius represents the total symbol size without showing the entire circle from which the segment came (Figure 8g). The wedge's point anchors it to its enumeration unit (the opposite association is used for graduated spikes; Figure 3b). *The Maritime Provinces Atlas* uses a grouping of four wedges set at ninety degrees, like four flower petals. Each wedge represents the amount of a particular type of overnight accommodation across the region. The reader may either compare entire symbol structures or individual segments of each symbol.

The segmented bars and squares were constructed with fifty-percent markers (Figure 8a, b, c, and d). Students often included these reference



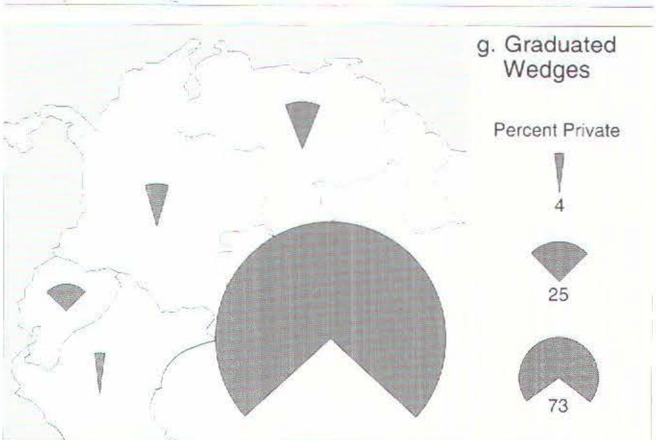


Figure 8. Linear and areal bivariate point symbols for a proportional data relationship: public and private disbursements are proportions of total 1993 disbursements. Example proportion representations are: graduated segmented bars (a), segmented bars of constant size (b), graduated segmented squares (c), segmented squares (d), graduated segmented circles (e), segmented circles (f), and graduated wedges (g). Figures b, d, and f show only the proportions of private and public disbursements and not the total amounts of disbursements, which are shown in a, c, and e. Figure g shows only the portion of private disbursements as circle sectors, or wedges, with an indication of the total-disbursement graduated circles in the square-root scaled sector radii.

points in their symbol designs, which assists accurate percentage estimates. The symbol form in Figure 8b is known to statisticians as a framed rectangle (Cleveland 1985, p. 208; Dunn 1987, 1988), and Monmonier (1993, p. 65) describes its usefulness in representing both absolute magnitudes and intensities. Dunn (1987) also suggests scaling the widths of the rectangles to total data values (to total disbursements for Figure 8b). In a conversation about Figure 8, MacEachren mentioned a successful student project from an ACSM design competition that divided graduated squares into ten-by-ten grids such that each cell represented one percent, and each row ten percent, of the whole for all symbol sizes (rather than using grid cells of a fixed size; a hybrid of Figure 8c and 2e).

CONCLUSION

The work of students new to cartography has been an inspiration. With modern computing at their disposal and freedom from the conventions of traditional thematic mapping, students are producing a wide variety of creative symbols for mapping data usually symbolized by graduated circles or squares. For example, a recent student assignment with economic data produced creative ideas ranging from a proportionally scaled Monopoly game character (with pockets turned out or clutching money bags) to weight scales drawn tipped to illustrate balances between dollar amounts (by Elliott Westerman and Erika Bozza respectively). Are these effective symbols? With so little research into multivariate representations, one can not say, but this type of experimentation can be encouraged until there is evidence to the contrary.

The intent of this paper has been to review some of the major topics on which graduated symbol research has been conducted and to demonstrate the wide variety of ways to map univariate data as well as bivariate comparison and proportional relationships. The survey was not exhaustive, but if it has inspired recall of other symbol forms that have been missed, then it has been successful in provoking consideration of the wide range of possibilities available with point symbols. Modern computer mapping allows mapmakers greater flexibility in designing creative graduated point symbols. This increase in flexibility increases the importance of research examining symbol design issues. As this article has illustrated, there are wide-ranging possibilities for applying creative, eye-catching symbol designs to summarize and synthesize quantitative spatial distributions.

". . . there are wide-ranging possibilities for applying creative, eye-catching symbol designs to summarize and synthesize quantitative spatial distributions."

ACKNOWLEDGMENTS

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Animation-Based Map Design: The Visual Effects of Interpolation on the Appearance of Three-Dimensional Surfaces

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Computer animation is a potential aid in map design, because it provides a means for quickly reviewing many design alternatives. This research is a conceptual exploration of one aspect of animation-based design: The effect of inverse-distance weighting on the visualization of three-dimensional maps. The primary variable examined is the inversedistance weighting exponent. Changing the exponent in small intervals allows the creation of a series of three-dimensional maps that can be assembled, and played back as a frame animation. In this procedure, cartographers can view the visual effects of various exponents on the resulting surfaces. Design-based animations allow mapmakers to visualize effects of their decisions in advance of map production and to make more informed design decisions. It is suggested that this method can be expanded to examine map design for a great many forms of cartographic symbology. Ideally, automatic frame generation and a graphic user interface should become an integral part of the development of these visualizations.

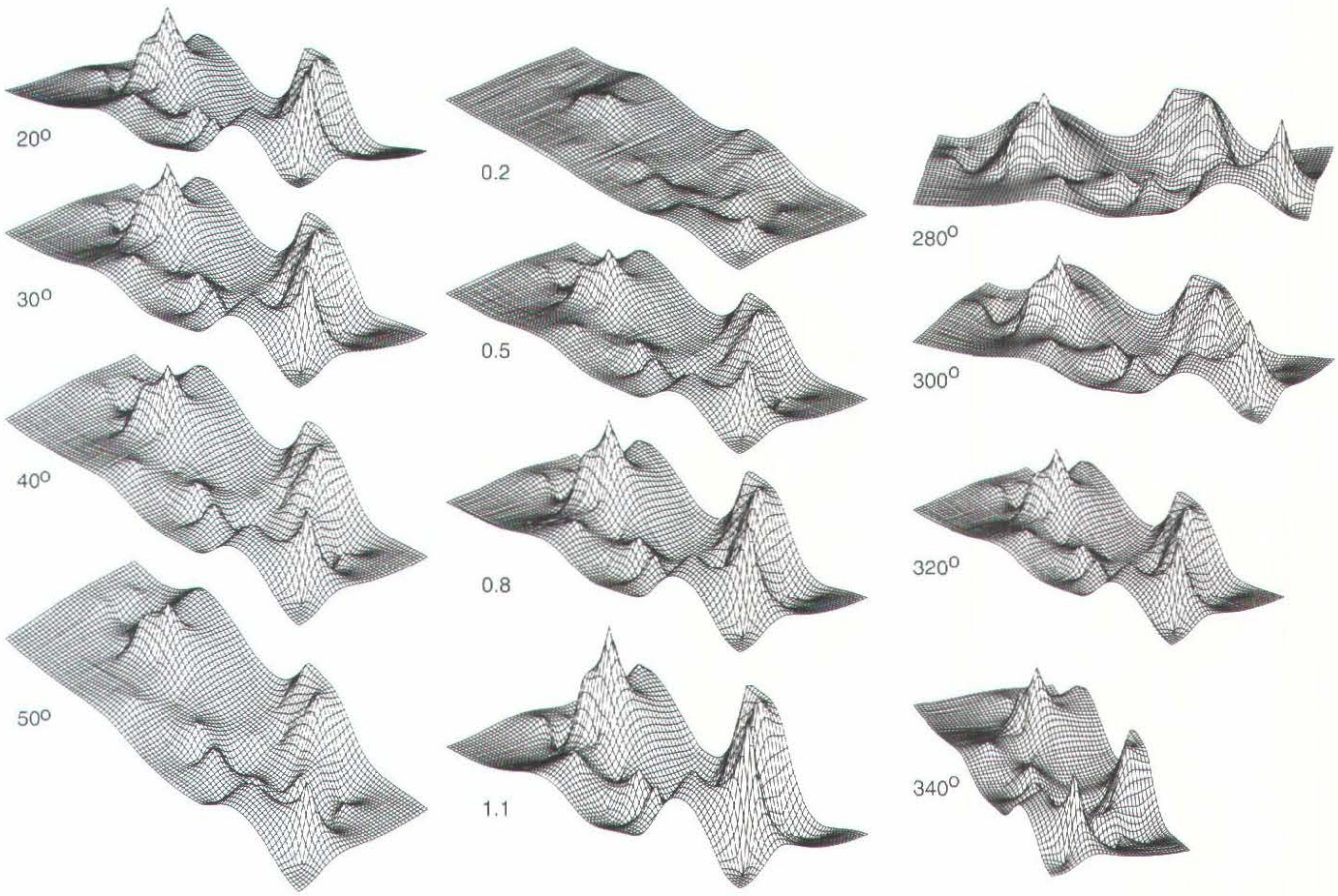
KEY WORDS

Animation, cartography, map, interpolation, inverse-distance weighting, map design, three-dimensional maps, visualization.

INTRODUCTION

The mapping of continuous geographic phenomena in three dimensions presents a significant challenge to the design-oriented cartographer. The challenge is a consequence of the variety and interplay of design decisions which, in various combinations, can radically alter the appearance of a map, and because of the greater than usual difficulty map-users have in interpreting three-dimensional maps (Rowles 1978, Jenks and Crawford 1971). Continuous spatial data is either measured or derived at control points, which, to a degree, are representative of the phenomena. In many cases, mathematical interpolation is then used to create a more extensive network of data values from which a visual depiction can be subsequently generated. The look of the surface is heavily dependent on choices made during interpolation, and these choices are numerous, including grid size and shape, search methods, and interpolation equations (Golden Software 1990). Depending on the interpolation methods selected and the parameters used in the interpolation algorithm, the resulting maps may give very different impressions of a single geographic data set.

Another set of design decisions are encountered following interpolation. These are decisions involving the visual orientation of the three-dimensional surface. These decisions deal more directly with visual map attributes, and for that reason, are more predictable in their visual manifestations than those involving interpolation. Figure 1 shows a variety of options including surface rotation, angle of view from the horizon, and vertical exaggeration, as well as a number of other controls that affect the eventual look of the surface. Although these choices can also profoundly influence map appearance, their effects are somewhat easier to anticipate than those involving the mathematical equations of interpolation. For



Vertical Angle. An angle of 90 degrees places the viewer directly above the surface

Vertical Exaggeration. A value of zero would show a totally flat surface.

Horizontal Rotation. A rotation angle of 360 degreesplaces the viewer due east of the surface.

Figure 1. Orientation variables in three-dimensional mapping

example, it is easier to envision what will happen to a surface if the angle of view above the horizon is changed from 30 to 50 degrees than it is to predict the visual effects of changing the inverse-distance weighting exponent from one to three. Consequently, this research is concerned with the more difficult case of visualizing the effects of interpolation decisions.

While it is true that contemporary three-dimensional surface-producing software allows experimentation with the effects of design choices on map appearance, this is usually accomplished one map at a time and normally requires many iterations before a satisfactory map is created. For example, SURFER (Golden Software 1990), a popular isoline and three-dimensional mapping program for Windows / DOS-based computers, permits the creation of one surface at a time, and does not give the user the capability to view a number of different surfaces in rapid succession. It is difficult and time consuming to compare the visual results of design alternatives, and this hampers the cartographer's ability to identify the most appropriate selections for representing data and communicating accurate and useful visualizations of geographic data.

"Animations are potentially valuable aids in selecting optimum ways of designing three-dimensional maps, representing data, and gaining a more complete understanding of geographic data through exploration of varying interpolation options."

Animations are potentially valuable aids in selecting optimum ways of designing three-dimensional maps, representing data, and gaining a more complete understanding of geographic data through exploration of varying interpolation options. Furthermore, many other types of cartographic symbols can be explored using similar methods. Although our focus is just one aspect of three-dimensional mapping, it is not unreasonable to assume that animation can be used to explore variations in unit-value in dot mapping, or the visual effect of varying isoline intervals, for example.

Visualization

Geographic visualization is an act of cognition through which mental images of geographic data which have no visual form are developed (Peterson 1995, MacEachren 1995). This notion of visualization can be extended to the realm of computer cartography in which data stored in computer memory can be displayed visually. Cartographic visualization of geographic data can facilitate examination and explanation of processes which evolve over time, over space, or a combination of both (Campbell and Egbert 1990). It is also a concept which focuses on the exploration of data rather than data presentation. As such, cartographic visualizations created with exploratory data analysis in mind are generated as animation sequences used to identify trends and relationships in the data. This identification which may or may not be observed in a non-visual setting, prompts new understanding of research problems or real world applications (MacEachren and Ganter 1990).

In our study map animation is used to construct a sequence of maps created by incrementing the weighting exponent in the inverse-distance equation. Visual differences between adjacent maps in the sequence may at first seem negligible, but examination of a lengthy animation sequence reveals pronounced variations as the weighting exponent increases. Clearly, animation enables mapmakers and map-users alike, to perceive differences which may otherwise go undetected when viewing a series of static maps, perhaps even the same maps that compose the animation. Animation adds a dimension to map interpretation and analysis that the viewing of individual static maps can not provide, just as the experience of viewing a motion pictures is quite different from looking at a sequence of individual stills from the same film.

"Clearly, animation enables mapmakers and map-users alike, to perceive differences which may otherwise go undetected when viewing a series of static maps, perhaps even the same maps that compose the animation."

This study is restricted to developing a case study whereby a sequence of three-dimensional surfaces is produced in which visual differences between surfaces are a result of small variations in the weighting value used in the inverse-distance weighting interpolation algorithm. Additionally, the method of control point search in interpolation was varied in one instance in order to provide a slightly different perspective to animation-based design in three-dimensional mapping. The sequence of changes in surface smoothness revealed by the animation allows map-designers to visualize and compare the effects of changing variables in the creation of three-dimensional surfaces.

"Animation adds a dimension to map interpretation and analysis that the viewing of individual static maps can not provide, just as the experience of viewing a motion pictures is quite different from looking at a sequence of individual stills from the same film."

Continuous Surface Interpolation

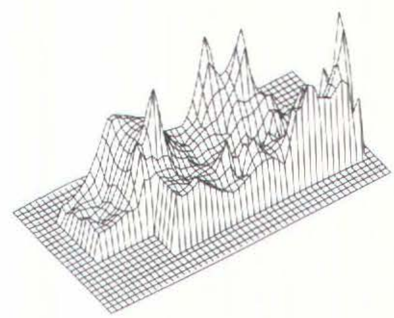
Interpolation of continuous geographic data for the purpose of three dimensional mapping provides estimates of data values for geographic attributes, such as precipitation and temperature, at unsampled grid points within the area of existing control points. The rationale behind all interpolation is that points close together in space are more likely to have similar values than points further apart (Monmonier 1982). Rather than drawing boundaries and generalizing the area around known control points as homogeneous, interpolation is used to model the expected variation of values within an area (Burrough 1986). Interpolated values are then used to generate a visual surface representative of the continuous nature of the phenomena being mapped.

The challenge of interpolation is to choose a technique which creates a plausible model of the variation between control points. Selection of the most appropriate method depends on the type of data used, the amount of computational time available, and the degree of accuracy required (Lam 1983), although this last factor is difficult to anticipate in advance. A wide variety of algorithms have been developed for point interpolation. For example, surfaces constructed by kriging, minimum curvature, and inverse-distance weighting interpolations are shown in Figure 2. As can be seen, variations in interpolation method can produce pronounced visual differences. Kriging is a regional variable theory technique that assumes an underlying linear variogram, and because of this it can produce an estimate of error associated with an interpolation (Burrough 1986, Sampson 1975). Minimum curvature keeps the grid surface fixed at known control points while iteratively applying an algorithm to smooth the gridded surface. Its primary benefit is that the resulting surface is constrained to pass through all control points (Golden Software 1990). Other interpolation methods include splines, polynomials, Fourier Series, Power Series Trend, and distance-weighted least-squares (Lam 1983). Each technique has a different way of modeling the variation between control points and produces a map surface with a distinctive appearance. Although it is beyond the scope of this paper to address benefits and liabilities of each interpolation method, consideration of these factors is an im-portant cartographic endeavor, and the reader is referred to an excellent summary of interpolation methods written by Burroughs (1986, pp. 147-166).

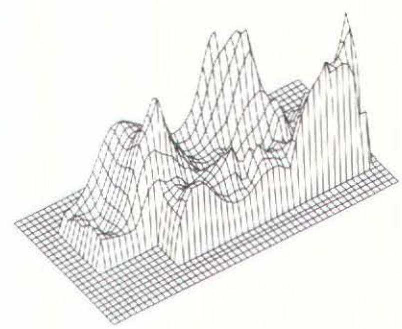
Inverse-distance weighting, the interpolation model used herein, was selected for several reasons. Inverse-distance weighting is a relatively simple technique, and due to its simplicity and availability in existing computer mapping software, is commonly used. Widespread application of this technique in cartography makes it a reasonable selection for demonstrating its visual manifestations. The general advantages of using inverse-distance weighting are that computation time is minimal, and the algorithm is relatively easy to understand (Burrough 1986). This last point will be discussed later in the section of this paper dealing with the detailed interpretation of changes seen in the maps due to variations in the interpolation weighting.

Most commonly, inverse-distance weighting is a type of moving average computation in which intermediate point values are calculated as an average value of a local neighborhood or 'window' (Burrough 1986). This aspect is also referred to as 'piecewise' because only a portion of the control points are used to calculate grid values, although all control points are sometimes used in interpolation (Lam 1983). By limiting the number of control points selected, local anomalies of the data can be represented without affecting the interpolation of other points on the surface (Burrough 1986). However, an inverse-distance weighting technique that encompasses all control points can be used to create a more generalized and smoother surface.

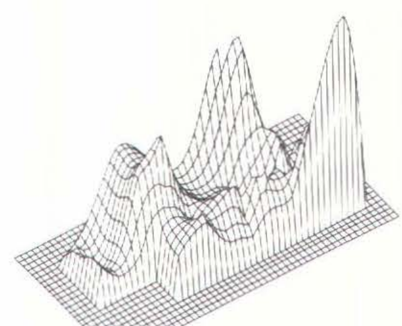
Because observations close together tend to be more alike than distant observations, distance between control points is a key element in the model. The contribution of each control point to the local average is based on its distance from the grid location. Distance is incorporated into the inverse-distance weighting equation as the quantity d, as shown in equation 1. The equation calculates a new data value (*Znew*) for each grid intersection (*I*) on the interpolated surface. The last variable to be discussed, and the most important to this research because its visual effect can be observed in the animations produced, is the weighting exponent (*wt*). As the weighting exponent increases, the influence of nearby points



Inverse Distance Weighting
(weighting = 2)



Kriging



Minimum Curvature

Figure 2. Examples of variations in three-dimensional surfaces resulting from three different interpolation methods. Data mapped are total July, 1995 precipitation for Nebraska.

$$Z_{new} = \frac{\sum (Z_i / d_i^{\,wt})}{\sum (1/d_i^{\,wt})}$$

where:
Z = z value
d = distance
wt = weighting value

Equation 1. Inverse Distance Weighting Equation

on the local average also increases while the influence of more distant points decreases. Emphasizing nearby points creates more peaks and valleys in the surface in contrast to the smoother appearance resulting from the use of a low weighting exponent which gives distant points more numerical equity in the computation.

A single set of data values located at control points can be subjected to inverse-distance weighting interpolation and then, by incrementally increasing (or decreasing) the weighting exponent in small numerical steps, a sequence of maps showing weighting exponent effects on visual surfaces can be generated. Maps thus generated can be played back as a frame-by-frame animation, and the effects of differences in the weighting exponent can be observed. This can be done for either isoline or three-dimensional maps, but only three-dimensional maps are used in this research. The mapmaker, after a thorough examination of the animation, can then choose the map deemed most appropriate for the mapping purpose at hand, or the model or theory being examined . This type of visualization through animation can serve as a map-design tool whose utility extends well beyond visualization of weighting exponent effects and into numerous other arenas of map design, in ways that Peterson first explored in his sequencing experiments with choropleth maps (Peterson 1993).

"Maps thus generated can be played back as a frame-by-frame animation, and the effects of differences in the weighting exponent can be observed."

Constructing the Animations

Data for the animations was acquired from weather stations across the state of Nebraska. A total of seventy stations were used. At each of these control points (locations shown in Figure 3), precipitation for the month of July, 1995 was recorded. Animation frames were created in SURFER, v 4.5 (Golden Software 1990), and then imported into Animator Pro, v 1.2 (Autodesk, Inc. 1991) for playback. Figure 4 shows a selection of frames from two of the animations that were eventually constructed.

Control points used in the animation were selected because these climate stations have fairly uniform spacing throughout the mapped area. Inverse-distance weighting interpolation is easily affected by non-uniform

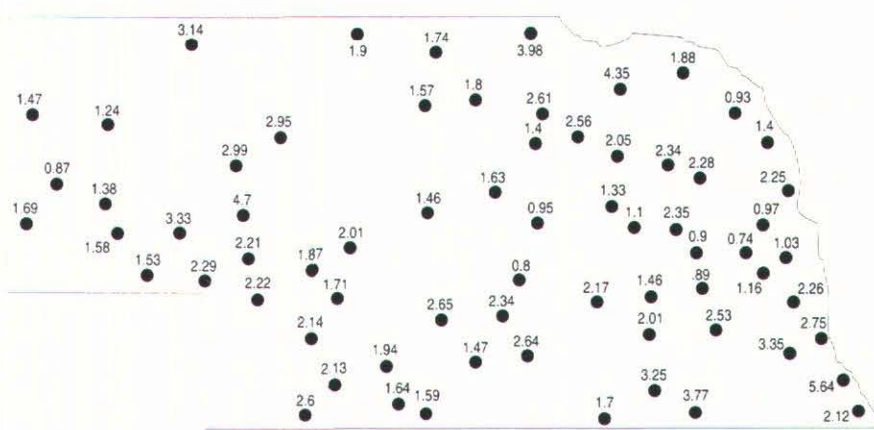


Figure 3. Location of control points and associated total July, 1995 precipitation values for the maps.

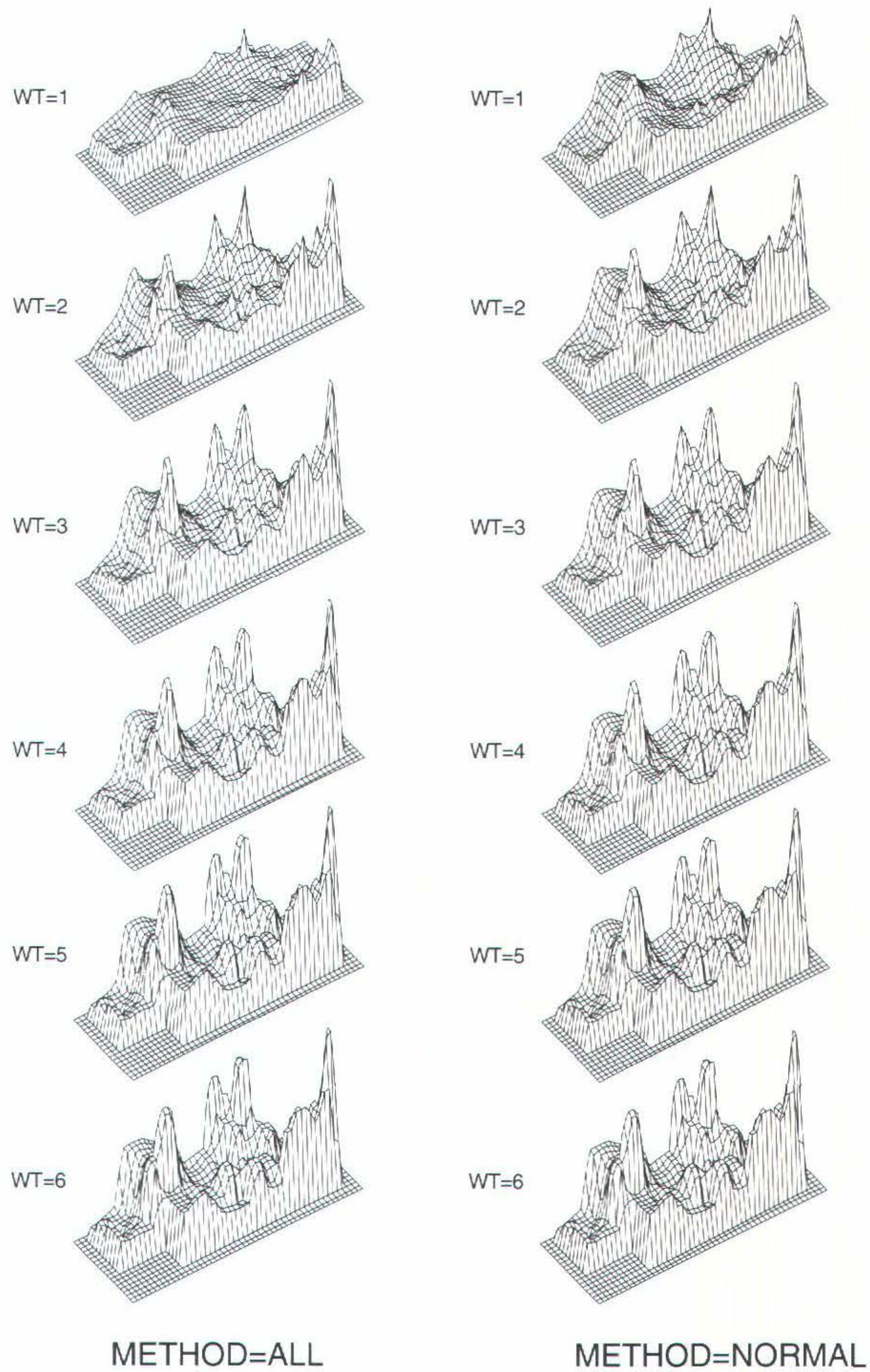


Figure 4. Frames selected from animations. Animations have a total of 120 frames. The method referred to as ALL uses all control point values in inverse distance weighting. The method referred to as NORMAL uses a regional selection of control points based on a selection of near-neighbors. WT is the weighting exponent.

distributions of control points because equal weights are assigned to each point even if it is in a cluster (Lam 1983). In reality, the mapmaker does not always have control over the locations of control points, but for the purposes of this study it was desirable to avoid the effects of uneven or clustered arrangements.

One long-standing, useful, and often violated convention in graphics and cartography maintains that the selection of symbols for maps and graphs should reflect the nature of data to be mapped (Tufte 1983,

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Robinson and Petchenik 1976, Dobson 1973). When studying the effects of inverse-distance weighting in three-dimensional animations, continuous data is most appropriate for visualization. Precipitation is a truly continuous geographic phenomena, and for that reason was chosen for animations in this study.

Individual animation frames (maps) were constructed in SURFER by entering control point x, y locations, and corresponding z-values (precipitation) for the seventy climate stations, and then computing the inverse-distance grid interpolation. For each successive frame, the weighting exponent was increased by a value of 0.05. This fairly small increment was chosen to produce a smoother animation, and one which lasted a sufficient length of time to allow examination of the visual effect of increasing weights. An attempt to utilize an increment of 0.1 was made but rejected because the animation appeared too discontinuous and jumpy between successive frames. Weighting exponents ranged from 0 .05 to 6, stopping at 6 because higher weights produced little change in the three-dimensional surface. This exponent range and numerical increment yielded a total of 120 frames.

Most visual parameters were set and remained constant throughout production of individual frames for each animation. In order to examine the visual effect of other interpolation settings, some of these settings were varied between animations. Uniform vertical scaling was used in all animations, and was selected by first displaying the surface with the greatest vertical relief (wt=6), adjusting the vertical scalar until no clipping of the surface at the edge of the screen occurred, observing the numerical index of the vertical scalar (in this case, an index of 1.5), and then setting all subsequent frames to that index value. Angle of view from the horizon and horizontal rotation of the surfaces were set, and also remained constant throughout the animations. Angle of view was set at 45 degrees above the horizon, and horizontal rotation at 235 degrees (0 being a view due west). For the precipitation data used in this study, this orientation was chosen because it was the best for revealing the peaks, valleys, and spatial trends of this rather complex surface, while it also minimized hidden surfaces. Once initial settings were determined, individual frames were produced and screen-captured to GIF file format at 640 by 480 resolution. Frames were then imported into Animator Pro for playback.

"Weighting exponents greater than four produced surfaces that appear to be identical. It was also observed that vertical relief increases as weighting exponents increase because increasingly greater weights are applied to fewer control points. This occurs regardless of control point search and selection methods."

Two variations of the animations are shown in Figure 4. Settings, as described above, are the same for each animation; the only variation is in the way control points were searched for and selected for interpolation. METHOD=ALL indicates that all control points were used to derive the interpolated surfaces, but they were still subjected to inverse-distance weighting. METHOD=NORMAL indicates that the number of control points was restricted to a set number of neighboring control points within a specified radius. One can observe that the animation produced as ALL has slightly smoother surfaces when lower weighting exponents are used. However, the surfaces rapidly become similar as weighting exponents increase. Further experiments with other search settings revealed the same trend. Weighting exponents greater than four produced surfaces that appear to be identical. It was also observed that vertical relief increases as weighting exponents increase because increasingly greater weights are applied to fewer control points. This occurs regardless of control point search and selection methods.

These observations are indicative, but not exhaustive of the utility of this sort of visualization, and the conclusions derived from our observations would have been difficult to arrive at by any other means. Selection of individual maps to be representative of an animation series will ultimately be determined by the author's purpose and goal, statistical considerations, the intended audience, and the author's knowledge of the geographic phenomena being mapped. In this regard, design-oriented animations can assist authors in making more informed map selections.

CONCLUSION

Animation-assisted map design is a promising tool for cartography, and can be extended well beyond animation of the visual effect of inverse-distance weighting on three-dimensional mapping. Virtually all variables encountered in designing and constructing three-dimensional surfaces can be animated, including data search procedures used in gridding, surface rotation, vertical scaling, and horizontal angle of view. The greatest potential for this method lies in examining design decisions whose consequences are difficult to visualize mentally, such as those dealing with the mathematics of grid interpolation. In a further example of related uses of animation, Figure 5 shows frames from an animation in which only the density of the interpolated grid is varied. Mapmakers can examine this animation to determine an appropriate level of grid-based generalization for the final product. The first frame (top) shows a surface that is made from a grid that is too coarse to give an adequate impression of a continuous surface, while the last frame's surface is made from a grid so fine that line symbols coalesce and obliterate portions of the surface. The animation shows that neither of these two choices, nor some of the other frames, would be appropriate. However, the actual selection of a surface must be made in consort with the purpose of the map, the mapmaker's intentions, and statistical guidelines, such as the error generated by interpolation. Animation-based design is not limited to examination of three-dimensional surfaces, and could just as easily be employed in examining design variables in isoline, choropleth, dot, and graduated symbol mapping, as well as other forms of symbolization, (DiBiase et al.1992). In order to become a truly useful design tool, creation of frames for animations should be automated, and the means for selecting variables for animations should be interactive and employ a graphic user interface (GUI).

Automated map generation is desirable because the construction of animations manually, one frame at a time, is a costly and time-consuming process. Unless animations can be produced automatically by interfacing a geographic data base with map construction software, animation-based design is not likely to be widely employed by cartographers. Availability of automated animation would provide a means to quickly construct and playback animations, make design decisions, and if a single map is desired, to produce the most appropriate map for display or publication.

The addition of interactivity and graphic user interfaces to auto-animation software gives even greater utility to animation-based design and exploratory data analysis as well (Peterson 1995, Lodding 1983). The interface should permit users to make design decisions by selecting data; interpolation method; design elements, either singly or in combination, to be varied through animation; legend structure and other ancillary map elements; and the number of frames. It should then render the animation and permit playback. The interface should allow the user to change animation speed, reverse the animation, pause and resume, and possibly to query the numerical geographic data base. Finally, the interface should permit the user to record their selections and produce a final map. In order for animation to become a robust means for design-based visualization, it is essential that these capabilities be repeatable. When this occurs, cartography will be closer to utility in the use of animation in map design and data exploration.

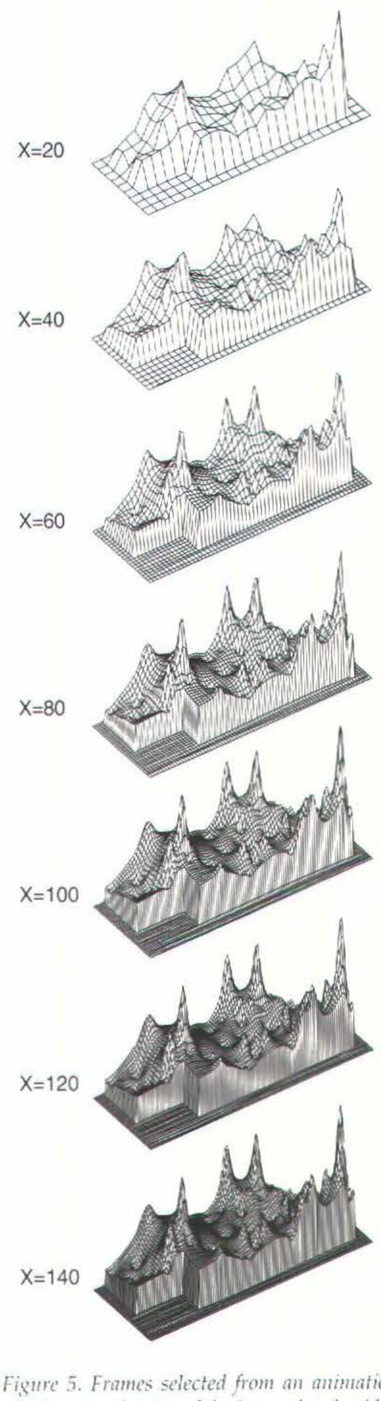

Figure 5. Frames selected from an animation which varies density of the interpolated grid using inverse-distance weighting. The weighting exponent is 2. X refers to the number of grid intersections on the horizontal axis.

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Decision-Making with Conflicting Cartographic Information: The Case of Groundwater Vulnerability Maps

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Conflicting cartographic information can cause problems when used to support planning decisions. Creation of conflicting information is becoming more common as geographic visualization and modeling software are used to develop multiple maps that represent different views of the same data. This paper presents groundwater vulnerability mapping as an example of information conflicts of this type. Three different vulnerability models applied to the same test data produced radically different results. This information was presented to a group of local planners to examine how they would deal with the conflicts. Through this exercise it became apparent that each planner used highly individual criteria to evaluate the results from the models. A continuum of strategies describes the range of responses from aspatial to spatial approaches. Jung's theory of psychological types is applied to further understand variation in responses. Avenues for further research are suggested in the representation of cartographic information conflicts, the role of psychological types in decision-making with maps, and the role of group dynamics in decision-making with maps.

INTRODUCTION

Conflicting visual information in cartographic representations is a potential problem in all map displays and geographic analyses. The use of multiple representations for both display and analysis has become common practice with the widespread use of geographic visualization and analysis software (e.g., geographic information systems - GIS). These software products aid in the generation of many different views of one data set, the comparison of different data sets, the use of different methods for processing data, and the construction of different analytical models. The use of these tools for purposes of visualization provides a context through which many additional insights about a topic may be gained. In this paper, the question of conflicting information in cartographic displays is pursued in order to assess variations in map use strategies and interpretations when information is contradictory. This issue became apparent during a project that investigated the use of GIS for implementing three different groundwater vulnerability models from the same data set (Rader and Janke, 1995). Different representations of groundwater vulnerability effectively illustrate the use of multiple views as suggested by Tufte (1990), Muehrcke (1990), and Monmonier (1991), since maps produced with these models supposedly represent 'similar' information. However, the maps (see Figure 1.) are quite dissimilar, and the conclusions derived from their use may be contradictory. Visual information conflicts such as these may be common to many GIS analyses.

"In many cases, decision makers fail to distinguish between the maps and the models that they represent."

Maps produced from groundwater vulnerability assessments are a primary information source employed by decision makers in developing landuse policy. Decision makers often have neither the original data nor the knowledge to assess the validity of the different models. In many cases, decision makers fail to distinguish between the maps and the models that they represent. With increased use of GIS and modeling techniques, multiple maps representing 'similar' information will likely be available and produce information conflicts for decision makers. Ultimately, knowledge about how people resolve problems with conflicting visual information should provide strategies for improving both cartographic displays and users' interpretations of these displays. To examine this question, a map use exercise based on maps from different groundwater vulnerability models was presented to a group of local planners, elected officials, and groundwater specialists.

The first part of this paper describes the vulnerability models, the context for their use, and a more formal problem statement. An overview of the map use exercise and the results are then presented. Finally, issues pertaining to the strategies that decision makers employ for dealing with visual information conflicts are discussed. In approaching this study, it is hoped that concrete recommendations can be provided on how to resolve information conflicts between maps. However, the participants' disparate responses indicated that the fundamental role of maps in decision-making was at issue and that diverse approaches to problems of conflicting information were in operation. Parallels with Jung's psychological typology are drawn upon to help understand variations in decision-making strategies. Finally, avenues for further research are suggested.

Conflicting Visual Information in Cartographic Representation and Planning

The potential for conflicting cartographic representations appears in several ways. The desirability of multiple maps for purposes of visualization has been documented by several authors. Tufte (1990) noted that small multiple maps are well suited for time series data; Monmonier (1991) suggested that multiple views of a geographic data set are more truthful (i.e., ethical) because they provide a comparative frame of reference; and Muehrcke (1990, 9) observed that a more thorough understanding may be obtained by using several different maps created from the same set of data. However, while additional insights may be generated through multiple views, visual information conflicts may arise if views display contradictory information. The question that should be asked is, what happens when map users are presented with conflicting or contradictory information?

". . . what happens when map users are presented with conflicting or contradictory information?"

Little work has addressed the problem of conflicting visual information between multiple cartographic displays. Typically, cartographic studies have examined map similarity and pattern comparison (Olson 1972, Monmonier 1974, Lloyd and Steinke 1976, Peterson 1985, and MacEachren and Ganter 1990). These studies have examined perceived relationships between several maps, impacts of map complexity, and map similarity. While these have provided a background for understanding the perceptual characteristics of map displays, the question of conflicts in information content between several maps remains. This becomes increasingly important in geographic information processing technologies where multiple displays may be produced from the same data set. For example, different views may be accomplished through changes in classing and symbolization schemes or the combination of multiple layers in overlay analysis.

Wood (1992, 186) suggests that presenting multiple "relationships constituted by the interplay of the data" is a desirable artifact of the mapping process. Muehrcke (1990) has extended this discussion to include the idea of "map stability." Map stability refers to whether or not changes in the way data are processed or symbolized have an impact on the message perceived. However, what happens when views directly conflict with one another? While seeing small differences in representations illustrates the impact of cartographic methods on displays, seeing large differences may call into question both cartographic and modeling methods and possibly their ultimate utility.

Planning involves the design and consideration of a series of alternatives. Monmonier (1991) reviewed the use of maps in zoning and environmental protection. Maps serve as tools for making planning decisions and communicating a plan's spatial implications. In DiBiase's (1990) continuum of visual thinking and visual communication, planning maps operate in both the private and public realms. The maps are used in planning policy decisions, essentially a thinking task, and in presenting planning policy decisions, essentially a communication task. In this context, the power of maps to persuade should not be overlooked (Harley 1989, Wood 1992). The 'official' nature of maps often operates at a subconscious level.

Monmonier (1991, 71) notes that "without maps, planning would be chaotic, furthermore even with maps, many would argue that planning is chaotic." In addition, he comments that errors in map compilation can be significant and that the same information is often used to develop different plans (Monmonier 1991). Planning scenarios often involve creating different conceptual models about a future reality. Different scenarios can often produce markedly different results. The 'stability' of results may be re-framed with the concept of 'model stability.' Model stability describes how representations change through the use of different models for combining data layers that were processed using the same cartographic methods. This is a case common to many GIS analyses that employ different conceptual models for describing a process. While individual data layers may have high map stability, the final maps made from different models may be unstable. The inherent stability or instability of the models may influence how decisions are made with different maps. The implementation of different models therefore has the potential to produce information conflicts. Conflicting information is a major source of chaos in the planning process.

"While individual data layers may have high map stability, the final maps made from different models may be unstable."

Groundwater Vulnerability: An Example

Maps that result from groundwater vulnerability models provide an apt example of potential cartographic information conflicts in planning. Beginning in the early 1970s, a variety of vulnerability models were developed in response to environmental concerns about drinking water. Significant health effects from drinking contaminated water have been documented; these include cancers (Armijo 1981; Lee and Nielsen 1987; Canter 1987), blue-baby disease (Lukens 1987), and central nervous system birth defects (Scragg et al. 1982). By the mid-1980s, it became apparent that planning and management tools were needed to identify places that have high vulnerability to contamination (Aller et al. 1985).

Several types of models have been developed to assess vulnerability. These models can be grouped into four major categories: hydrogeologic setting models, parameter weighting / scoring models, empirical models, and simulation models (Geraghty & Miller, Inc. and ICF, Inc. 1990). Hydrogeologic setting models use qualitative site-based assessments to rank the relative vulnerability of different areas with varying geomorphic, geological, and groundwater characteristics. Parameter weighting / scoring models numerically rank and weight susceptibility factors and calculate relative vulnerability scores for areas with different hydrogeologic characteristics. Weights are often assigned to account for variations in the relative importance of factors in particular situations, e.g., areas with thin soil. Empirical models use data that relate known occurrences of contaminants in groundwater to hydrogeologic characteristics through the application of leaching models or statistical inference. Finally, simulation models attempt to predict contaminant leaching through interactions between hydrogeologic characteristics and contaminant fate, such as dilution, breakdown, absorption, and volatilization (Geraghty & Miller, Inc. and ICF, Inc. 1990, 6-1).

Most of the models that have been applied in the context of GIS have been hydrogeologic setting or parameter weighting/scoring models. DRASTIC (Aller et al. 1987) is a general-purpose, parameter weighting model that was developed for the US EPA for vulnerability assessments at county and state levels. Several other models have been developed for state-wide assessments, including the Wisconsin Susceptibility Model (WISM) (Schmidt 1987), which uses weighted hydrogeologic characteristics to model vulnerability, and an aquifer vulnerability model of Michigan (Lusch et al. 1992), which uses hydrogeologic characteristics for determining relative risk. All of these models use a combination of data layers that include soil, subsurface geomorphic characteristics, geology, recharge rates, and topography.

Little research has addressed differences in model performance. The authors of the models often state that results from different models are not directly comparable (Aller et. al 1985; Schmidt 1987). Furthermore, Merchant (1994) notes that there is little validation of these models in the context of GIS and that there are a number of questions concerning the impact GIS processing methods have on model performance. Rader and Janke (1995) implemented several models popular in Wisconsin to address the question of model differences. In applying the models, the data layers and processing methods were held constant so that variations in the results were due to differences in model design.

"The basic problem is that even when using a common data set processed in the same way, the results are vastly different."

Three models were used: SCAM (Soil Contamination Attenuation Model) (Zaporozec 1985), WISM (Wisconsin Susceptibility Model) (Schmidt 1987), and DRASTIC (Aller et al. 1985). All are parameter scoring/weighting models that use several data layers, although not all models use all of the layers, nor do they consistently weight the layers. Maps derived from the three models for a site in St. Croix County, Wisconsin are displayed in Figure 1. The basic problem is that even when using a common data set processed in the same way, the results are vastly different. It is important to reiterate that the models' developers state that the models are not directly comparable. Regardless, it is likely that the maps represent the same thing to the lay person and many decision-makers.

Statistical analysis of the relationships between the models further corroborate the visual disparities (Table 1.). Correlation coefficients demonstrate little or no relationship in the SCAM -DRASTIC pair and very weak relationships in DRASTIC-WISM and WISM-SCAM pairs. The comparison map and coefficients of areal correspondences between the models indicate complete divergence over 22 percent of the area, with similar ratings between two of the three models over 70 percent of the area, and complete correspondence over 7 percent of the area. The coefficient of areal correspondence only indicates agreement or disagreement across the models. Therefore, the models produce conflicting risk ratings, both graphically and statistically.

Maps produced from these assessments are often the primary information used by officials for making landuse policy decisions concerning groundwater. Often, officials neither have the data nor the knowledge to assess the validity of the models. This has led to the following question:

> Given that groundwater vulnerability models produce different results and, therefore, different maps, how do decision makers respond when confronted with conflicting cartographic information?

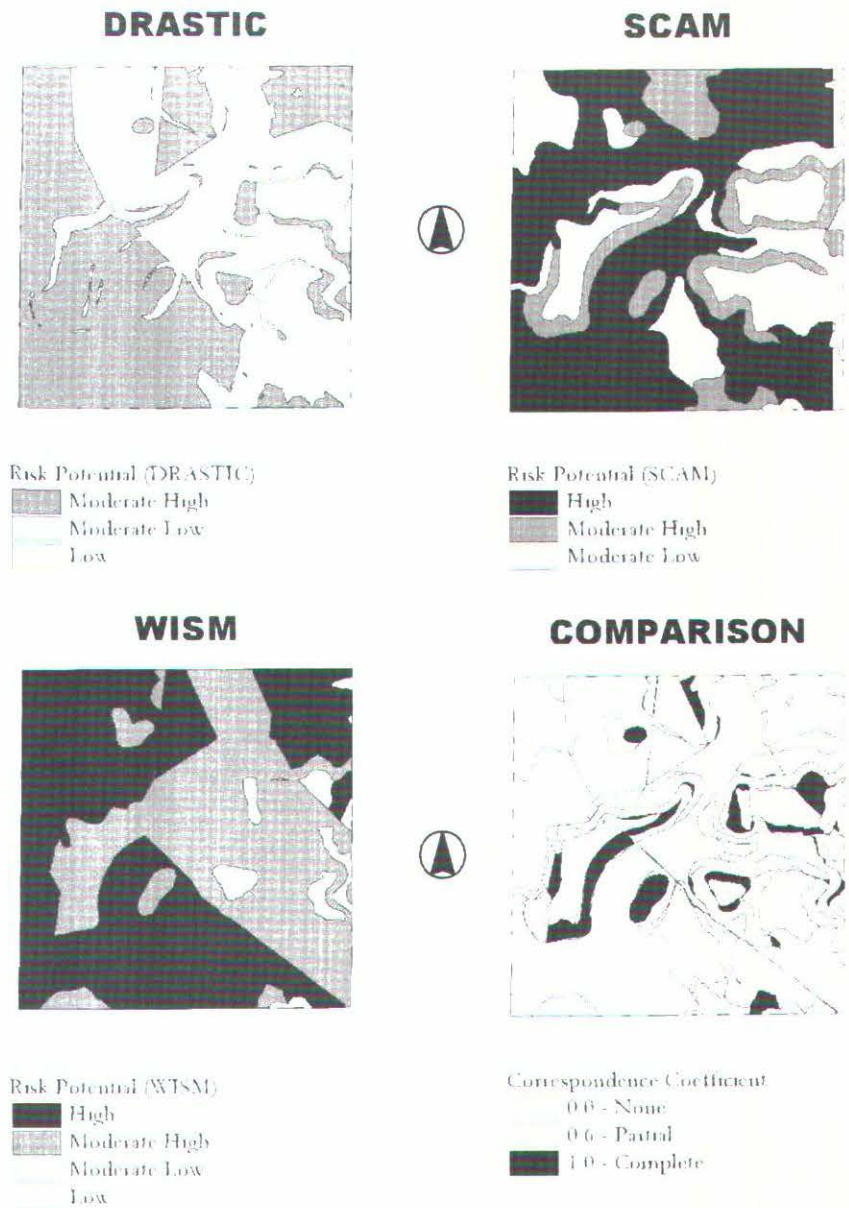


Figure 1. Groundwater Vulnerability Model Results

In asking this question, an attempt is made to understand how visual data impact decisions, especially where multiple views of the data present conflicting information.

METHODS

In order to examine the impact that conflicting visual information has on planning decisions regarding groundwater protection, the study was designed using the three conflicting maps seen earlier in Figure 1. While the models are not explicitly designed for site-level assessments, they serve a function in screening sites for further consideration. In all cases, a site-level assessment would need to be conducted prior to a final decision.

"While the models are not explicitly designed for site-level assessments, they serve a function in screening sites for further consideration."

Thirteen local decision makers participated in the map-use exercise. These people were chosen because they represent typical users of vulnerability maps in planning-based decisions. The participants included five planners, three local government board members, two geologists, one civil engineer, one developer, and one farmer. Only three of the thirteen

Correlation Coefficients (standardized unclassed scores)		Coefficient of Areal Correspondence (classed scores)	
SCAM-DRASTIC	0.049	None	22.4%
DRASTIC-WISM	0.279	Partial	70.3%
WISM-SCAM	0.311	Complete	7.3%

Table 1. Relationships between Groundwater Vulnerability Models

participants had significant experience with groundwater vulnerability models and mapping.

"The exercise had the participants identify potential sites for houses using the information on groundwater vulnerability for each of three different maps."

The exercise had the participants identify potential sites for houses using the information on groundwater vulnerability for each of three different maps. Each map was divided into four quadrants. Participants were asked to assume that all sites were equally accessible within each quadrant and that each site would have its own well and septic system. For each map, they also rated the vulnerability for each quadrant, chose the best location for a house in each quadrant, and selected the overall best quadrant for a house. A sample test page is reproduced in Figure 2. From these questions, information on perceived relative vulnerability levels and locational behavior were obtained. Such site selection problems are realistic and critical tasks for planners.

The three specific task questions were:

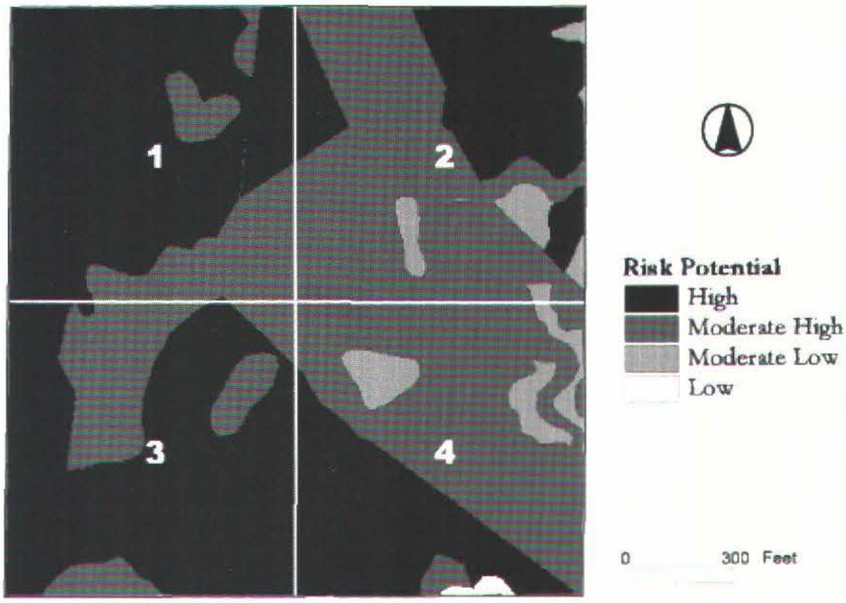
1) Based on this map, rate the average risk for groundwater contamination in each of the four quadrants using the scales below.
2) Based on the information on the map above, mark the best location for a house in each quadrant with a dot. Assume that all locations are equally accessible and that each house will have its own well and septic system.
3) Examine the map above. Which quadrant contains the most desirable location for a house? You must choose one.

In designing the test pages, the three maps were simply labeled as Areas 1, 2, and 3. Since the vulnerability maps had extremely low correlation coefficients (0.049 - 0.311), the maps were not rotated or flipped to mask that the maps represented the same area. In general, as the correlation coefficient of the map pairs falls below 0.84, it becomes increasingly more difficult for subject to judge similarity (Olson 1972). None of the participants noticed that the maps represented the same area during the exercise. This slight deception was later revealed to the participants and formed the basis for a discussion of how to resolve information conflicts between the maps.

"Participants were then asked to describe how they would resolve the information conflicts between the maps, considering that the maps represented the same area."

Once the participants answered the three sets of questions, they were given a description of how the different maps were constructed using a GIS. At this point, the fact that the three maps represented the same area was revealed. Participants were then asked to describe how they would resolve the information conflicts between the maps, considering that the maps represented the same area. After answering this question individually, participants were divided into two focus groups for a discussion of the models and an opportunity to examine how information conflicts might be resolved in a group setting. Each of the authors facilitated one of the groups and transcribed the discussion. After the focus groups finished, each participant responded to a questionnaire on their previous experi-

Groundwater Vulnerability Area 3



Question 1. Based on this map, rate the average risk for groundwater contamination in each of the four quadrants using the scales below. (Circle the number that most closely matches your rating)

Quadrant 1 Low Risk High Risk
Average Risk Assessment 1 2 3 4 5 6

Quadrant 2 Low Risk High Risk
Average Risk Assessment 1 2 3 4 5 6

Quadrant 3 Low Risk High Risk
Average Risk Assessment 1 2 3 4 5 6

Quadrant 4 Low Risk High Risk
Average Risk Assessment 1 2 3 4 5 6

Question 2. Based on the information on the map above, mark the best location for a house in each quadrant with a dot. Assume that all locations are equally accessible and that each house will have its own well and septic system.

Question 3. Examine the map above. Which quadrant contains the most desirable location for a house? You must choose one. 1 2 3 4

Figure 2. Test page for WISM Model from Map Use Exercise

ences with vulnerability maps and models and their uses in landuse planning.

RESULTS

Analysis of variance (ANOVA) was used to test the relationship between the vulnerability ratings for each quadrant. The results indicated that the participants' average vulnerability ratings in all but one quadrant were significantly different (*p* less than .05) between most map pairs. (See Table 2.) Quadrant three (SW) was the only quadrant where the ratings were similar between all maps. Overall vulnerability ratings for each map were compared using ANOVA, and all map pair comparisons were significantly different (*p* less than .01). Therefore, the participants' perceived vulnerability ratings were significantly different. This indicates that the maps exhibit a potential for information conflicts.

*"The results indicated that the participants' average vulnerability ratings in all but one quadrant were significantly different (**p** less than .05) between most map pairs."*

Quadrant four (SE) was judged by the participants to be the most suitable location for a house on all of the maps. This quadrant also received the lowest average risk ratings for each of the maps. This indicates that even though there were significant differences in vulnerability ratings for this quadrant, it was still the best general area for a house. In this

Quadrant 1	Quadrant 2
SCAM-DRASTIC*	**SCAM-DRASTIC***
DRASTIC-WISM*	*DRASTIC-WISM*
WISM-SCAM*	**WISM-SCAM***
Quadrant 3	**Quadrant 4**
SCAM-DRASTIC	*SCAM-DRASTIC*
DRASTIC-WISM	**DRASTIC-WISM***
WISM-SCAN	**WISM-SCAM***

***SIGNIFICANTLY DIFFERENT at p < .05**

Table 2. Vulnerability Ratings between Map Pairs by Quadrant (ANOVA)

context, the information content was reasonably stable. In other words, the maps produced the same result for the determination of the best quadrant for a house although the maps were different.

The best location for a house within each quadrant varied by map (Figure 3.). It is not surprising that in areas where locational choices are constrained, more clustered patterns occur. SCAM and WISM models provided high constraints, and therefore the participants' responses tended to cluster. These clusters occurred in different locations in all quadrants except quadrant three (SW). The DRASTIC model, in contrast, had fewer constraints on location. The patterns produced were dispersed in the northern quadrants, and as constraints became more severe, the patterns became more clustered in the southern quadrants. The southern clusters occurred in different locations on all three maps.

DISCUSSION

Differences in both vulnerability ratings and locational preferences indicate that different results would be obtained depending on which map was used for analysis. The problem, as stated, is what happens when people are confronted with two or more maps that present contradictory results. It is important to remember that the results produced with the different models were based upon the same data set, although the models incorporated the data in different ways.

To examine how people deal with conflicting cartographic information, the following question was asked:

> Given that these results were developed from the same data set, for the same area, and yield conflicting information, describe how you would deal with this in the context of making planning decisions?

After writing a response to this question on their own, each participant joined a focus group for a discussion. This allowed an examination of both individual and group decision-making strategies and to ask additional follow-up questions concerning the use of the maps and their utility.

"Some participants suggested throwing out the maps completely and using 'common sense.' "

After examining the individual responses, a number of similarities and differences in participants' comments were noted. Responses varied by how important maps were to the decision-making process. Some participants suggested throwing out the maps completely and using 'common sense.' Others defined the problem as political, referring to administrative and zoning codes that dictate acceptable procedures and regulations and require minimal map use for arriving at a decision. In the middle, some participants suggested using a combination of the models or using the models as 'advisory to decision-making.' Finally, some participants suggested 'improving existing models or developing new models' that would provide more valid maps.

The importance of the map and spatial approaches to the problem varied greatly. These approaches could be characterized by a continuum from aspatial to spatial (Figure 4.); with less reliance on the map defining the aspatial end and more reliance on the map defining the spatial end of the continuum. The implicit assumption at the aspatial end of the continuum is that the map is unnecessary. Common sense, unreflective opinions, or rules-of-thumb fall at the aspatial end of the continuum, because they often do not explicitly consider local ecological conditions. For example, "everyone knows that you don't put your well next to your septic system." While initially these may appear to be spatial approaches, these approaches do not involve the evaluation of specific site characteristics. In certain circumstances, for example, in areas with deep wells, the 'rule' may have little practical meaning. The issue is that one does not need map-based information to apply the rule. The implicit assumption at the spatial end of the continuum is that a map is needed, but that the existing models need to be refined.

The question arises, why do people view the utility of maps (and models) with such divergence? There are many different possible explanations. One could be that the participants were drawn from a varied pool of expertise, and individual differences in background, education, training, experience, and decision-making roles could account for these variations. Another possibility is that participants placed different interpretations on the context of the problem. However, responses from individuals with similar backgrounds ranged across the full continuum. For example, the planners made comments that ranged across the continuum in spite of their similarities in training and decision-making roles. Therefore, it appears that individual cognitive style, irrespective of training or context, may be a more significant factor in explaining how people deal with conflicting cartographic information.

In the broader context of cognitive psychology and human behavior, Jung (1983, 129) also questioned how individuals could interpret the same material so differently? Jung concluded that people belonged to different psychological types and these types accounted for variations in individual decision-making processes. The basis of Jung's typology consists of four dichotomous variables: introversion / extraversion, intuition / sensation, thinking / feeling, and judging / perceiving. These variables combine to form 16 different psychological types. Jung (1983, 132) stated that there are never pure types and that all individuals exhibit varying degrees of all characteristics. A type is defined by the predominant mode of behavior. Readers may be more familiar with the extension of this work on personality types by Myers and Briggs (Myers 1962).

Keirsey and Bates (1984, 23) note that Jung proposed all of the dimensions, but never fully developed the judging / perceiving dimension. Jung emphasized introversion / extraversion as the predominant distinction between psychological types. Introverts emphasize the inner world of concepts and ideas, and extraverts emphasize the outer world of people and things (Myers 1980, 7). The other psychological functions describe how people perceive, come to conclusions, and come to closure. Intuition and sensing, according to Jung (1983, 144), are "the irrational functions" and relate to the perception of events or potential events. Intuition involves indirect perception, and sensing involves direct perception through the five senses (sight, sound, smell, touch, and taste). Thinking and feeling are "the rational functions" and relate to how conclusions are made. Thinking involves the use of logical processes aimed at an impersonal finding, and feeling involves processes based on subjective values (Myers 1980, 3). The final dimension, judging and perceiving, involves preferences

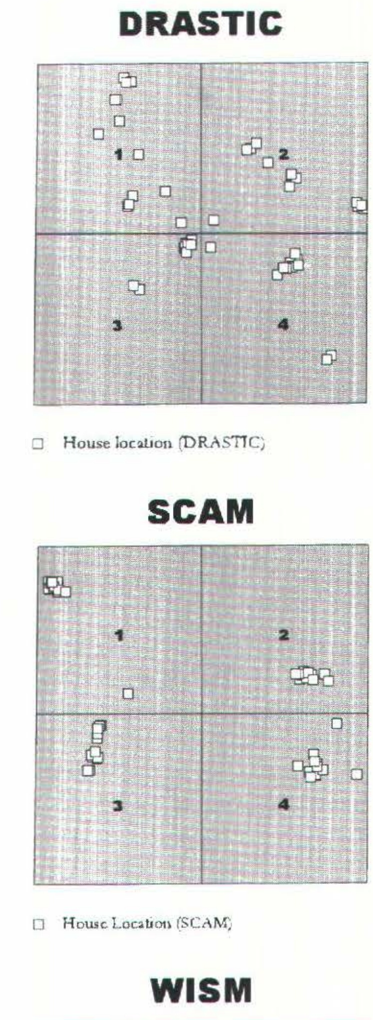


Figure 3. Most Desirable Location for a House by Map.

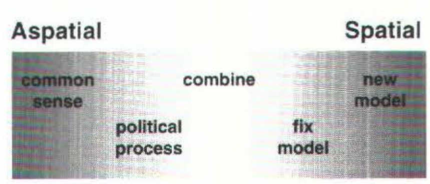


Figure 4. Continuum of approaches for handling conflicting cartographic approaches.

Figure 5. Continuum of psychological types and spatial decision-making.

for degrees of closure. Judging types prefer closure using the available data, and perceiving types defer closure desiring more data.

Returning to the idea of how participants made decisions using the maps, it is possible to arrange several of the psychological functions along a continuum from aspatial to spatial (Figure 5.). This provides a potential framework for explaining the variations in approaches to conflicting information on maps. Common sense approaches align with intuition and feeling and generally appear to be aspatial, whereas modeling approaches align with sensation and thinking and appear to be spatial. Spatial and aspatial are defined solely on the basis of whether or not a map is necessary to the decision-making process. Furthermore, intuitive types prefer approaches that are figurative and employ approximations; in contrast, sensing types prefer approaches that are literal and employ detailed facts (Kroeger 1992, 33). Common sense involves "unreflective opinions" (G. & C. Merriam 1987, 266), rather than careful evaluation of facts. As noted earlier, since common sense does not rely explicitly on site-specific criteria, the aspatial end of the continuum is defined as being largely intuitive. In contrast, the spatial end involves the use of site-specific criteria for evaluation and, therefore, is largely based on sensing.

"Spatial and aspatial are defined solely on the basis of whether or not a map is necessary to the decision-making process."

It is important to note that these psychological dimensions describe a continuum of approaches to decision-making behavior, and each is valid in its own right. These define predominant decision-making preferences and it is possible for people to shift style in some circumstances. The predominant type of introversion/extraversion and the functions of perceiving/judging do not appear to play a role in this context.

Variations in psychological types influence group dynamics in decision-making. The interaction of contrasting types has the potential for increasing both understanding and misunderstanding. This became apparent in our focus group discussions where participants expressed a number of contrasting opinions about the utility and necessity of the maps. In group decisions, people cannot assume that everyone is perceiving and evaluating the data in the same way and therefore will arrive at the same decision. In the focus groups, we observed contrasts in psychological types; decision makers exhibited both aspatial and spatial behaviors as described above. The fact that the maps presented conflicting information may have reinforced each participant's preexisting tendencies toward a psychological type. Those that tended toward the aspatial end of the continuum readily discounted the validity of the maps and their importance to decision-making. In contrast, those that tended toward the spatial end of the continuum looked for refinements to the models in order to improve the maps. In this situation, the discussions were congenial, since no decision had to be made. However, the dynamics in groups that need to make a decision are often less congenial.

"In group decisions, people cannot assume that everyone is perceiving and evaluating the data in the same way and therefore will arrive at the same decision."

At the outset of this project, the application of the Jungian typology was not anticipated, however, this typology provides a way to frame the problem and provide some explanation. Contrasts in styles have a potential for helping to understand how people process and manage conflicting information in a cartographic context. In contexts where multiple decision makers interact to solve a particular problem, in this case policy concerning groundwater vulnerability, diverse decision-making styles come into play. The likely result of varied decision-making styles is multiple outcomes that are internally consistent to the individual decision makers because each person frames the problem context according to her/his psychological type. Diverse results should serve as a reminder to those who are cartographically oriented that not all users approach maps with the same enthusiasm. This alludes to an issue of how we approach conflicting information as a cartographic problem; the problem is not necessarily a question of 'how maps work', but instead, 'how people work with maps'.

SUMMARY AND CONCLUSIONS

In this paper, results were presented from an experiment that investigated how decision-makers respond to conflicting cartographic information using a series of conflicting groundwater vulnerability maps for one area. Thirteen local decision-makers participated in the experiment, and input was collected from them as to how they would deal with information conflicts in a planning situation. The decision-makers then discussed the maps and information conflicts in a group setting to examine how group dynamics might influence the decision-making process. From this, a continuum of strategies was developed that ranged from the aspatial approaches, e.g., discard the maps and use common sense, to spatial approaches, e.g., build a new spatial model that "works."

When the research was initiated, it was viewed as a problem of cartographic visual information processing and it was anticipated that the participants would discuss methods for representing conflicting information. However, the issue turned very quickly away from the original maps to one of how decisions are made using or, in some cases, not using the maps. This allowed the development of a continuum of approaches to the problem and a series of questions as to why such diverse results were obtained. It became apparent that very different internal processes were employed by the participants to evaluate the map data. The divergence of responses suggested that something as fundamental as Jung's psychological types may play a role in how people evaluate map data.

"However, the issue turned very quickly away from the original maps to one of how decisions are made using or, in some cases, not using the maps."

The results from this study present several avenues for further research. The first avenue deals with how to best represent information conflicts and uncertainty between multiple maps. With growing reliance on GIS modeling in environmental decision-making and issues of inter-model stability, methods need to be developed to spatially represent agreement and disagreement between models. MacEachren's (1994) suggestions provide a starting point for such an investigation. The second avenue deals with the role of individual preferences in decision-making and the influence of psychological type on how people work with maps. It is apparent from this research that there are diverse ways in which individuals perceive and understand information and that this may impact the decisions which they ultimately make. Finally, a third avenue deals with how groups make decisions using maps. The dynamics of individuals and groups in the decision-making process are markedly different, and little cartographic research has addressed this interaction.

The role and importance of multiple representations in visualizing spatial problems is well documented, however, there needs to be a concern with the quality of the information that these multiple views present. The potential for conflicting information in cartographic displays becomes quite high when multiple data layers are combined in GIS models. The fact that the same data layers may produce markedly different maps when combined in different combinations or through different models is coming to be a real concern for those who deal with environmental data and decision-making. This concern becomes paramount in situations where different representations may confuse or obscure understanding rather than illuminate it.

"The role and importance of multiple representations in visualizing spatial problems is well documented, however, there needs to be a concern with the quality of the information that these multiple views present."

ACKNOWLEDGMENTS

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reviews

The Dartmouth Atlas of Health Care. The Center for the Evaluative Clinical Sciences, Dartmouth Medical School. John E. Wennberg, Principal Investigator and Series Editor, Megan McAndrew Cooper, Editor. Chicago, Illinois: American Hospital Publishing, Inc., 1996. Pp. xiv + 230, maps, graphs, tables. $75 (softcover, academic discount, without diskettes); $350 (hardcover, with diskettes); $1,300 (hardcover, with diskettes, CD-ROM, and all nine regional supplements). ISBN: 1-55648-163-2, soft-cover. (Ordering information: AHA Services, Inc., P.O. Box 92683, Chicago IL 60675-2683, 1-800-AHA-2626).

Reviewed by:
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Every now and again a revolutionary approach to the processing and presentation of information appears, changing forever the way in which the subject matter is viewed and understood. The publication of *The Dartmouth Atlas of Health Care* may be an example of one of these events. In this slender volume (this reviewer examined the soft-cover academic version of the atlas; hardcover and electronic versions are also available), the project team has assembled numerous maps and vignettes representing statistical analyses of literally tens of millions of health care services, patients, and clinicians in a highly readable and interpretable format. The atlas portrays the current macro-scale spatial structure of the American health care delivery system and displays patterns of disease prevalence and treatment modalities for numerous health conditions and diseases. It may take a generation of medical geographers, epidemiologists and health services researchers to pursue all of the research questions, hypotheses and intuitive hunches derived from this single publication.

Most of the maps in the atlas display variations in health-related phenomena across hospital referral regions. These functional regions are aggregates of 3,436 hospital service areas which were defined through an intensive analysis of Medicare hospitalization data for 1992-93 in which five-digit ZIP codes were grouped into contiguous regions based on patterns of hospital use. A total of 306 hospital referral regions were identified through examining where residents of each hospital service area were referred for major cardiovascular surgery and neurosurgery. A series of detail maps show the locations of each hospital referral region in relation to major centers of health care (p. 25-35). Having defined the hospital referral regions, successive sections of the atlas provide detailed maps of acute care hospital resources and expenditures; hospital capacity, utilization, and outcomes; health manpower (physicians); diagnosis and surgical treatment of common medical conditions.

There are also sections on benchmarking, tabulations of much of the data presented in the detailed maps, and the strategies and methods used to develop the information and maps in the atlas. Most of the maps consist of two facing pages, with a standard layout that includes a national map with five insets (San Francisco, Chicago, Detroit, Washington-Baltimore, and New York) with the distribution of values for the phenomenon of interest grouped roughly into quintiles. Each discussion also includes a distribution graph showing the phenomenon of interest as the vertical axis and each hospital referral region represented as a filled circle of equal size. These graphs show not only the degree of dispersion, but also whether variation is due to relatively few outliers or is widely distributed across the nation. The text accompanying each map focuses on which hospital referral regions had high and low rates, but provides little interpretation of the data displayed. Some context is provided elsewhere. For example, prior to the section on spatial patterns in the diagnosis and surgical treatment of common medical conditions, there is a discussion of "which surgical rate is right?" and the issues of underservice and the role of scientific uncertainty in the delivery of health care services.

While *The Dartmouth Atlas of Health Care* is an impressive achievement, it is not without its shortcomings. Foremost among these is the failure to include a bibliography would link the methods used to the literature on health services research and medical geography, and would connect each statistical map to its empirical research base. To aid in interpreting the maps with data across hospital referral regions, a map showing populations in each region would have been useful. Most of the disease and treatment data are derived from the Medicare population, which is defined primarily by age and almost universal participation. Researchers interested in patterns of health care use among individuals under the age of 65 will be disappointed in the minor omission of maps for more than 80% of the population. There are no maps showing patterns of injury or disability, survival following specific treatments, obstetrical procedures and outcomes, or spatial variation in propensity to use inpatient facilities among the non-elderly. This omission is perhaps understandable, given the lack of standardized, nationwide population-based databases on hospital services other than Medicare, yet there are some datasets (national vital statistics data, for example) which, although not wholly satisfactory for analyses at this scale, could supply data with which to address some of these issues. The section on benchmarking, while interesting, is far too abbreviated to be of use to those interested in applying these techniques to the planning or evaluation of regional health care delivery systems.

These criticisms notwithstanding, this atlas is a monumental accomplishment which all practitioners of health services research or medical geography will wish to examine. Geography and map libraries should definitely add this volume to their holdings, and will find the hardcover edition consulted frequently. Spatial data repositories should consider acquiring the CD-ROMs with the detailed data used to generate the maps and graphics included in the atlas.

This reviewer looks forward to the linkage of spatial analyses of variations in health care delivery to decision-making by health care organizations, insurers, policy-makers and health services researchers, and to expanded and updated future editions of this atlas.

Mapping an Empire: The Geographical Construction of British India, 1765-1843. Matthew H. Edney. Chicago: University of Chicago Press, 1997. Pp. xv + 340, maps, references, biographical notes, and index. $35.00 hardback (ISBN 0-226-18487-0).

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Enlightenment ideals, brute colonial realities, and practical bureaucratic negotiations collide in Matthew Edney's history of cartographic practice during late eighteenth and early nineteenth-century British imperial expansion in South Asia. Considering recent studies on the duplicitous role of geography in European colonialism, it is not surprising that Matthew Edney has closely investigated cartography in British India. His contribution to the study of geography and empire is to present a sophisticated explanation of mapmaking in British India as a cultural, political, and historical product. Rather than a ubiquitous tool for empire, mapmaking in the divided bureaucratic context was confined, often contradictory, and incomplete. The author's narrative brilliantly synthesizes text and context —map and motive— to tell a story of how the British mapping of India was contingent on a variety of competing practical and ideological interests. Throughout this book, Edney deploys a rigorous theoretical analysis on voluminous archival material to illustrate the central theme in *Mapping an Empire*: A tension between Enlightenment epistemological ideals of observation and notions of representation were manifested through the actual practices of survey and mapmaking "on the spot." Moreover, this cartographic project based on intersecting ideologies of colonialism and contradictory ideals of science was mediated through colonial institutional negotiation and historical contingencies.

The first section of *Mapping an Empire*, Edney draws from many empirical examples to outline how overarching Enlightenment ideas and cultural expectations of "science" influenced colonial practices of mapmaking in the early years of British colonialism in South Asia. For example, the reports by "peripatetic officers" surveying the Indian landscape, such as Colin Mackenzie's Survey of Mysore (1800-1801) and Francis Buchanan's Bengal survey (1807-1814), attempted to achieve the ideal of taking a complete inventory. Survey of town locations, land resources, and rivers, descriptions of language and religion, social and economic information, mineralogical, botanical and zoological inventories were predicated on the notion that the surveyor could achieve a complete scientific understanding of the landscape through this implicitly cartographic and visual framework. According to Edney, observation and reason provided a "powerful rhetoric of vision, empiricism, and presence" that buttressed the scientific authority of imperial cartography (p.75). This cultural and ideological expectation that science must be a rational process of compilation set the groundwork for the construction of what Edney names as the geographical "archive." This "archive" includes representations, images, narratives, and maps assembled and ordered that underpinned the larger cultural process of colonialism.

Scientific expectation also framed the conceptual scope, process and practice of colonial mapmaking. Edney illustrates how the British understood vision and observation in the scientific process. He argues that scientific investigation was an exercise of power, explains how the picturesque landscape aesthetic fashioned images of South Asia, and outlines how an implicit cartographic framework structured geographical narratives that contributed to the colonial archive. Emphasizing the cultural and scientific influence of the cartographic perspective on more general imperial information gathering activities, the author observes that "geographical observation implicitly constructs new knowledge based on the spatial and distribution of phenomena, in which respect is firmly rooted in the map and mapmaking, but observation itself is part of the larger knowledge discourses constituted by texts, maps, images, and statistical censuses" (p. 46). Through his broad overview of British cartographic history in South Asia, Edney supports the notion that knowledge is intimately linked to power, but he grounds this perspective on detailed discussion based on the specifics of British colonialism in South Asia.

Edney connects these scientific ideals to imperial realities and moves his analysis from how geographical perspectives fashioned images of South Asia to how surveys and cartography were used to "discipline" the Indian landscape. Statistical, astronomical, and route surveys formed the backbone of colonial cartographic knowledge. However, for eighteenth-century colonial administrators, the potential of the survey was only realized when it was incorporated into a larger knowledge base, reconciled with multiple geographical sources, and systematically reconstituted in a single encyclopedic cartographic archive. Yet, according to scientific expectations, the information was obtained only through the inchoate and imperfect vision of the surveyor. For the cartographic project to progress scientifically, the surveyors needed to find new, more comprehensive and "rational" methods of mapping the empire. What Edney emphasizes is that technological change to triangulation concommitantly transformed the practices of cartography in British India. The innovative trigonometrical survey provided the "technological fix" to the acknowledged imperfect, indirect, often ambiguous route surveys, descriptive topographies, and astronometrical observations. Triangulation created a "rigorously structured space" supported by more accurately controlled measurements and provided the framework for more detailed surveys to be integrated at large scales. Trigonometrical surveys ordered cartographic space and disciplined the Indian landscape to European science. This new expensive and time-consuming cartographic method reduced the Indian landscape to a uniformed mathematical framework and set in motion a geographical certitude that fostered, ironically, practical material and intellectual anarchy that became characteristic of British mapmaking in India.

The scientific and cultural ideals of cartography also met financial limits, logistical constraints, institutional inertia, and stochastic colonial realities. Conditions of the colonial administration circumscribed all efforts to coherently map India. The divided information management system, patronage, hierarchical decision-making apparatus, separation between governmental departments, lack of resources, and expanding need for geographical information all contributed to a chaotic practice of mapmaking. Moreover, these structural constraints exacerbated the tension between surveyors and Company cartographers in London offices who eventually compiled the multifarious surveys into the single vision of India. This permitted a "mini-hierarchy" of cartographic expertise to form. As Edney writes, "The surveyors worked at the boundary between the uppermost, British portion of the pyramid and the lower foundations staffed by Eurasians and Indians; the cartographers functioned close to the pinnacle of the pyramid, collecting data and disseminating maps downward as necessary" (p. 162).

Edney focuses on the Madras surveys (1790-1810) to best illustrate the contingent character of British cartography as both duplicitous in advancing British claims on indigenous resources and divided in its practice. Lack of administrative unity was the prevailing characteristic in the mapping of Madras. Different motives and visions of how to make an accurate and comprehensive map in accordance with scientific and cultural expectations characterized this era of mapmaking. Notable illustrations of this cartographic anarchy are Edney's discussion of Colin Mackenzie's attempt at a systematic topographical survey, William Lambton's trigonometrical survey of India's eastern coast, and the inability of the government to create a single cartographic institution to coordinate a comprehensive survey of southern India. These enlightening examples illustrate how, through detailed archival research, one can empirically link internal administrative conflicts and financial constraints of cartographic practice to contested ideas in cartographic practice. Edney shatters the image of the ubiquitous colonial state unified in purpose, perspective, and practice. With sound empirical evidence, he shows that cultural expectation of "science" and social realties within the British colonial system had a profound effect on the construction of geographical knowledge.

The territorial expansion of British rule during the early nineteenth-century demanded a unified cartographic project to deal with increased governmental responsibilities. As a result, the British instituted the Great Trigonometrical Survey to support the publication of the *Atlas of India*. In the final chapters of *Mapping an Empire*, Edney writes a comprehensive history of this attempt to map "all of British India." The *Atlas of India* was intended to unify disparate topographical surveys based on a common "geometrical groundwork" of the Great Trigonometrical Survey of India (GTS). This framework that underpinned the *Atlas of India* "held the promise of a perfect geographical panopticon" to combine both geodetic science and general geography, thus reducing geographical data to a uniform reference (p. 319). The complexity of this section is found within the empirical examples of how the unified image of India developed historically within the changing requirements of colonial administration to rule their newly acquired territory. Edney's discussion on the Great

Trigonometrical Survey and its institutional development provides the reader with fundamental understanding how the character of British cartography in India was contingent on cost and, most of all, practical and ideological compromise.

Archival synthesis and lucid narrative of the ideological, historical, and technological processes of British mapmaking sets a new empirical and theoretical standard for both the history of cartography and South Asian colonial studies. *Mapping an Empire* takes the analysis of maps and power to a higher level of empirical precision and detail. He details cartographic practices and explains these within the context of colonial demand and constraint with the accuracy of a historian and precision of a cartographer. The cartographic specialist will appreciate how Edney brilliantly integrates a profound understanding of the practical process of mapmaking with voluminous archival material. His ability to expose important practical details of colonial mapmaking—from the problems with manpower, expense , and time limits— reinforces the broader theme that cartography is a highly contested process within divided colonial administration and limited resources. In *Mapping an Empire,* these logistical constraints are superimposed on the cultural expectations of science to show how the very fabric of geographical knowledge—the map—is socially and politically constituted. For the colonial historian or cultural geographer interested in questions of empire and geography, Edney demystifies the colonial state in the process of imperial expansion and brings into focus the role of individuals and colonial institutions that have profound effects on how the British proceeded to map India. *Mapping an Empire* is both a monumental contribution to the history of British colonialism and a necessary addition to the libraries of geographers interested in the history of geographical thought.

Atlas of Oregon Wildlife: Distribution, Habitat, and Natural History. Blair Csuti, A. Jon Kimerling, Thomas A. O'Neil, Margaret M. Shaughnessy, Eleanor P. Gaines, and Manuela M. P. Huso. Corvallis: Oregon State University Press, 1997. 512 pages, 670 maps including full-color map insert, 442 illustrations. Hardbound, $39.95. (ISBN 0-87071-395-7)

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The *Atlas of Oregon Wildlife: Distribution, Habitat, and Natural History* is a comprehensive publication featuring information on Oregon's 426 native terrestrial vertebrate species that breed in Oregon and 15 introduced species. In the heart of the atlas there are sections covering Amphibians, Reptiles, Breeding Birds, and Mammals, with a page dedicated to nearly each of the 441 species. Each page contains a two-color, 1:4,300,000 scale, range map with supporting textual information on Global Range, Habitat, Reproduction, Food Habits, Ecology, and other relevant facts. Reference to Order, Family, State and Federal Status, Global and State Rank and Species Length are also listed. Each page contains a finely created line-drawing of the featured animal. The maps display the probable ranges where each wildlife species could be found, using shaded relief and county boundaries as spatial reference. Csuti states, " The maps presented here serve as a guide to habitats and general distribution of each species." The breadth and depth of the information on wildlife presented in this atlas is evidence of a major collaborative effort. Many organizations are listed in the acknowledgments. The key contributing agencies include the National Biological Service, Oregon Department of Fish and Wildlife (ODFW), U.S. Environmental Protection Agency, Oregon Natural Heritage Program, and the Geosciences Department at Oregon State University.

The Atlas is well-organized with an extensive Introduction describing Oregon's wildlife and the methods used in compiling the range information. This section also includes a description of each of the 30 identified wildlife habitats of Oregon. Reference maps displaying the major transportation network, cities, and counties are conveniently located just before the species range maps. The atlas contains a glossary, an extensive reference section, a though index, and three appendices; (I) Checklist of Terrestrial Breeding Vertebrates, (II) Checklist of Wintering Birds, and (III) Winter Bird Distribution Maps.

The process used for the creation of most of the range maps started with the creation of a vegetation cover map derived from Landsat image interpretation. These vegetation cover types were then clustered into wildlife habitats based on habitation by similar groups of species. A full-color 1:750,000 scale Oregon Wildlife Habitat Map insert displays the habitat types and the

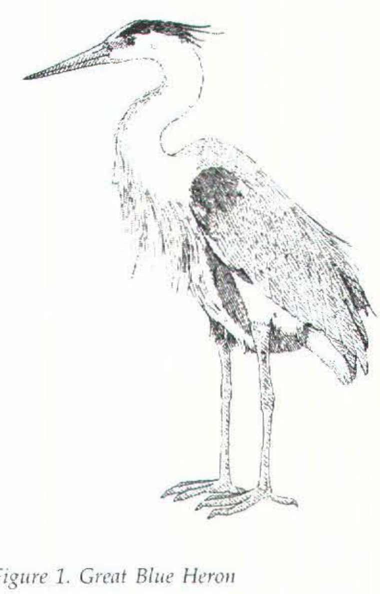

Figure 1. Great Blue Heron

vegetation cover boundaries. This mapping effort was part of the Oregon Wildlife Habitat Gap analysis project. The habitat types were then overlaid with geographic units of county, physiographic division, and a network of 441 equal-sized Environmental Monitoring and Assessment Program (EMAP) hexagons covering the state. The geographic units contained information on presence or absence of the species based on biological studies, museum records, and historical observations dating back to the journals of Lewis and Clark (1804-1806). This overlay process provided resultant range maps that were then reviewed by biologists, and whose input was used in cartographic fine-tuning of the final range maps.

Figure 2. Northern River Otter

Because of the characteristics of the species habitat or the available data, several methodologies were developed to create selected species maps by either modifying the ranges derived from the modeling method mentioned above or by using an entirely different approach. Some of the resultant maps from the modeling received additional attention by including major hydrographic features for species, like the northern river otter, that are closely associated with water, with the hydrography printed in a higher value ink. Other species such as the mallard duck or western pond turtle have a very discontinuous habitat which is denoted with a stippled area pattern for the range symbology. For marine birds a not-to-scale buffer off the coastline was generated to display their habitat. Two introduced species - the big

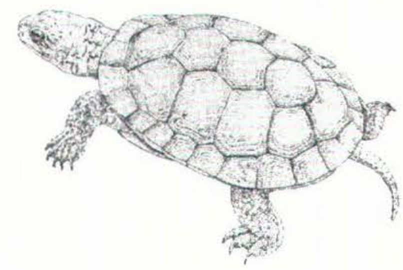

Figure 3. Western Pond Turtle

horn sheep and wild turkey - are based on maps directly from the ODFW using no GIS modeling. Other species ranges were modified with elevation data, for example, Townsend's mole was eliminated from the Coast Range. Some of the rare species are represented as point symbols plotted at known localities, the solitary sandpiper has one location. The mule deer and black-tailed deer are the only two subspecies that were mapped in the Atlas. The authors handled this problem by using two different values of ink, darker for east of the Cascades Range (mule deer) and lighter for west of the Cascades Range (black-tailed deer).

The authors of this atlas truly need to be congratulated on successfully publishing in an easy-to-access and easy-to-use format a tremendous amount of geographic information system data on a subject of great interest to the Oregon public. In the introduction, Csuti touches on this basic function of the atlas, "While the information gathered for GAP Analysis is maintained as digital data in a geographic information system, this atlas provides a larger audience with access to current knowledge about Oregon's wildlife." The OSU Press is already gearing up for a second printing, attesting to the popularity of the subject matter and the quick acceptance of the Atlas.

The layout and design of the pages is clean and easy to read. The use of teal-colored ink for the title and subtitle makes navigating through each page uncomplicated. The complementary use of range maps, species drawings, and descriptive text of micro-habitat conditions on a single page to communicate probable places where a species could be found, work very well together. The species drawings really help bring to life the atlas pages. With a little, or for some a lot of, imagination a reader can close their eyes and actually see a belted kingfisher perched on a branch over the quick-moving upper Deschutes River, watching and waiting for its next meal, or possibly a western pond turtle basking in the sun on a mudbank above a small pond in the Willamette Valley.

Interesting but less inspiring than the drawing and range map of the western pond turtle is the tie the atlas designers make between the atlas pages and the large-format Wildlife Habitat insert map. Stating which habitat type specifically is related to each species would have made a stronger connection. Even though the data represented on the insert map is the basis for most of the range maps in the atlas, its publication with the Atlas appears to be an afterthought. Unlike the maps on the Atlas pages, the insert map could be characterized as a GIS analysis product, produced on a medium-resolution inkjet plotter. The 1:750,000 map design is lacking in reference information, only displaying the county boundaries in addition to the habitat and vegetation types. This map could have been a great addition in helping meet one of the purposes the authors state: "They (the maps) can direct you to areas where field studies can determine if a species has found the right combination of habitat elements that enable it to establish and maintain a population." Having little or no spatial references diminishes its effective use as a location tool. Base GIS themes of major transportation, populated places and hydrography and elevation including shaded relief are readily available from the Oregon State Service Center for GIS and could have been added as a subtle background to help with location.

As mentioned above there were actually several methods of compilation for the range maps. The need for a legend on each map to help clarify these different compilation methods would have been an aid in understanding the meaning of the different symbologies used. For example, the difference in the point symbols used in the solitary sandpiper (location from a scientific report) and the smooth general boundaries used for the big horn sheep (ODFW non-modeled range) in comparison to the very detailed range boundaries generated by the GIS modeling for the pronghorn are all very different in appearance but there is no legend to clarify the differences. By studying the introductory text, an explanation of the variation in symbology becomes clearer.

I feel there is a need to point out a minor issue in the citation regarding the first delineation of the physiographic divisions of Oregon. The author writes that " The physiographic provinces of Oregon were first delineated by Franklin and Dyrness (1973)...". Further searching reveals that Franklin and Dyrness *Vegetation of Oregon and Washington* (1969) cite Baldwin (1964) and Baldwin in *Geology of Oregon* (1964) cites Dicken's *Oregon Geography* "... The geology is discussed regionally following physiographic divisions outlined by Dicken (1955) ..." I hope future editions address this point.

Beyond the few weak points just covered the atlas is a great success. This atlas can be held up high as an example to many cartographers contemplating assembling a state wildlife atlas. In a broader context, this atlas serves GIS professionals as an excellent example of making accessible to a large audience a complex GIS database that was originally generated for a specialized research and planning project. The citizens of Oregon are very lucky to be the recipient of this comprehensive book. This atlas is an educational tool that could lead to a greater awareness and sensitivity among Oregon's human population of the other inhabitants in their state.

Note: To view the range map of the northern river otter you can go to the web site <http://bufo.geo.orst.edu/brc/temp> and open *nrottmap.gif*. It is also possible to obtain a copy of the map image through the ftp site <bufo.geo.orst.edu>, and log on as anonymous. Change directories to *pub*, and "get" either the compressed tiff-format files, nrottmap.zip for PC users, or nrottmap.tif.gz for UNIX users.

cartographic techniques

GIS Data Made Manageable for Cartographic Production

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Background:

The widespread adoption of Geographic Information Systems (GIS) technology by government agencies and the private sector has made vast quantities of digital data readily available to cartographers. Initially, the high cost of hardware and software, low to medium quality graphic output, and limited data sets made GIS less attractive to cartographers. The practice of scanning and tracing output from GIS plots or importing vector line work into graphics programs were the primary options offered to transform GIS data into a computer format for the production of high-quality map products. Most cartography labs adopted the use of graphic arts applications such as Adobe Illustrator® or Macromedia Freehand® as digital tools for map production. Even though these software packages were fully capable of importing the points, lines, and polygons from the GIS, these programs could not take advantage of the useful attribute information that is maintained in the GIS database.

At the NACIS XVI annual meeting in San Antonio, many attendees were introduced to Avenza Software, Inc.'s MAPublisher® through a workshop. The MAPublisher software developers addressed the issue of maintaining the valuable attribute data and manipulation power of a GIS within Freehand or Illustrator. MAPublisher version 2.1 incorporated 38 filters designed to import vector and raster data with complete attribute tables intact for several major mapping software file formats: ESRI ArcView shape, ESRI ARC/INFO generate, MapInfo mid/mif, USGS DLG and SDTS, AutoCAD DXF and geo-referenced TIFF and JPEG. In addition to basic import capabilities, MAPublisher enabled the user to change the native projection of the imported files and create supplementary graphic databases.

In April of 1995, the Florida Resources & Environmental Analysis Center (FREAC) began the second *Water Resources Atlas of Florida (WRAF)*. The editors and cartographers found that most of the data previously submitted by the authors via hard-copy maps and tables were now maintained in extensive GIS data sets. MAPublisher performed beyond expectation when addressing these new data formats. All GIS points, lines, and polygons were imported with their accompanying geographic accuracy and attribute tables without error. However, some obstacles beyond MAPublisher's control were discovered while importing GIS data.

Often the data were far too detailed for use within the atlas. The level of precision and number of points originally created in the GIS caused difficulty when importing files. Freehand 7's internal limit of 32,000 points, for example, restricted larger ARC / INFO coverages from being imported. The coastline files often required considerable simplification as the base maps in the *WRAF* were much more generalized. MAPublisher enabled queries to be performed separating data into useful groups. Attribute tables were created or edited within Freehand without having to edit in an external spreadsheet or database. Once the points, lines, and polygons were imported, Free-hand's simplify [*Xtras/Cleanup/Simplify...*] routine was applied to remove unnecessary points. The [*Amount: 0.25*] was realized as the optimal level of simplification, eliminating the most points while maintaining path shape. MAPublisher's functionality provided a means of streamlining the large GIS data set and making final maps more attractive and accurate.

The following example illustrates how MAPublisher assisted in the construction of a graphic for the WRAF. The production was done using a 200 MHz Pentium Pro workstation with 64MB RAM running Microsoft Windows NT® 4.0 operating system software, ESRI ArcView® 3.0a, Macromedia Freehand 7.02, and Avenza MAPublisher 2.1 application programs.

Method:

Note: all keyboard shortcuts are shown for the Windows / PC OS. For Mac OS use simply substitute the Command key for the Control key (Ctrl).

For this example, three ARC / INFO export files (.e00) were acquired from the South Florida Water Management District's planning / GIS division for a combined map. The files included a south Florida coastline (sf_shoreline), 1996-water quality data by hydrologic basin (complete_wq96) and point locations of hazardous waste sites (hazard) (FIGURE 1).

Once imported into ArcView, the coverages were converted to shapefiles. It is good practice to keep the component parts of the shapefile (.shp, .shx, and .dbf) together as MAPublisher's built-in routines search for them when importing.

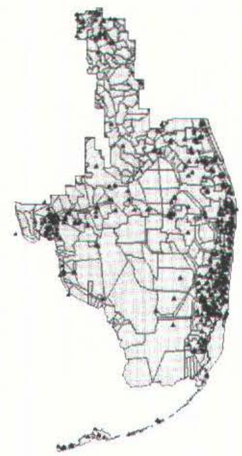

Figure 1. ArcView Display

Importing data through MAPublisher into Freehand was quite straightforward. The import menu [*Xtras/MAPublisher/Import...*] offers the options in logical pull-down menus (FIGURE 2). In addition to file format and feature type, the user must specify scale and page location for the element that is being imported. Within the pull-down fields the interface offers convenient browsing capabilities to locate files. In order to maximize the image, the default scale can be selected and the resulting image will fill the current page. For visual purposes, this was found most useful in the *WRAF*, as the graphics were to be re-scaled to standard basemaps.

To begin map construction, the shapefile of south Florida's coast-

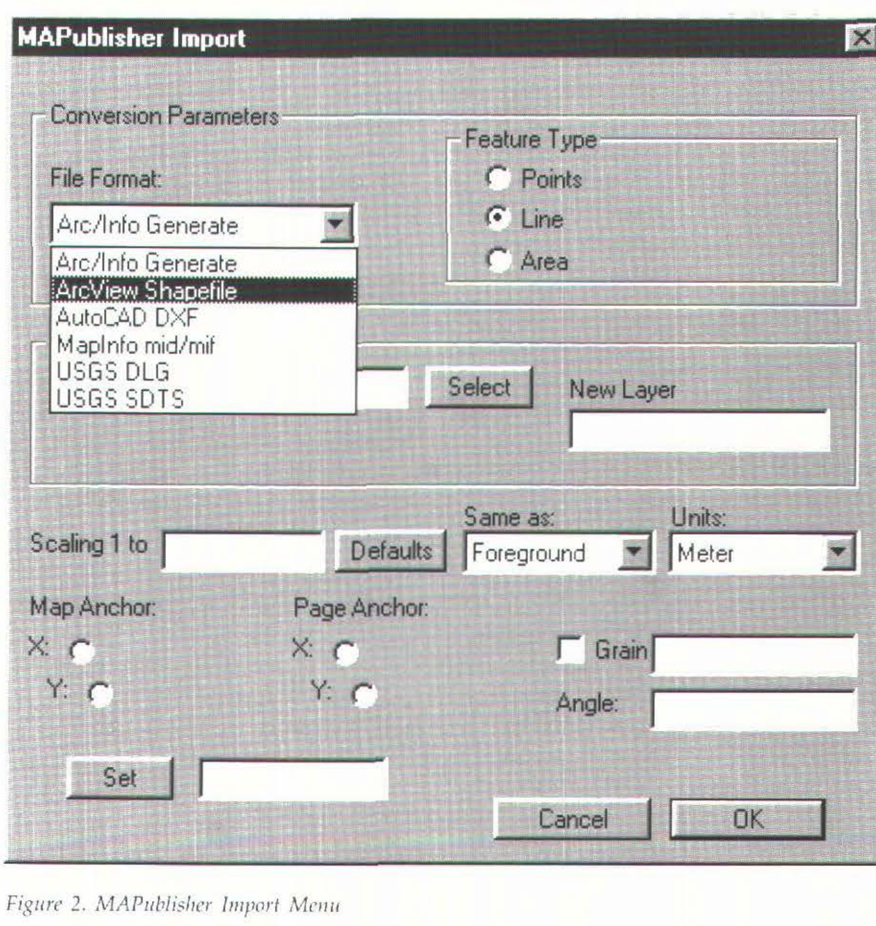

Figure 2. MAPublisher Import Menu

line was imported first for registration purposes and the establishment of default values (FIGURE 3). A search button complements the filename field of the menu making it

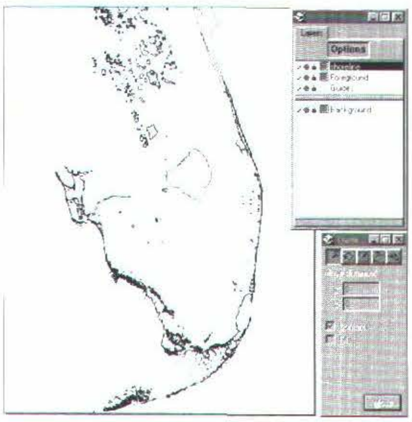

Figure 3. Imported Shapefile

unnecessary to commit the "8-dot-3" GIS filenames to memory. It is efficient to have each layer projected to the same coordinate system. However, re-projection of the data is possible using MAPublisher's projection editor [*Xtras / MAPublisher/Projection Editor...*]. Pull-down menus give access to 119 different projections and 42 ellipsoids contained in the filter (FIGURE 4). This feature was not used because the files in the sample were all projected to state plane coordinates. Default values were chosen for the scale, page and map anchor features so the data would be bound to the current page size. MAPublisher creates and labels the new layer the filename of the import by default. This can be modified, but it was found that for file management purposes, the default was preferred. For the waste site layer, the *shapefile* format and *point* feature type were specified. Once a file has been imported, the scale in which it was brought in becomes an option from the pull-down field. Selecting *Same as: sf_shoreline* commits the successive layers to the scale of that layer. This step is repeated until all of the shapefiles have been imported. It is recommended that all of the files be imported before any manipulation takes place. Premature resizing of an image or individual layer can result in inaccuracy.

With the three shapefiles imported, it was determined that the individual types of waste sites and water quality values for the final map needed to be extracted. When the attribute tables of the imported shapefiles were examined, legend categories were established. The waste site coverage included three types of facilities: National Priority List (Superfund), state-funded, and landfills. Water quality was designated as either good, fair, poor or unknown. MAPublisher's query features [*Xtras / MAPSelect by Attribute...*] enable the user to create selections using SQL type logic statements (FIGURE 5). Because this was the first query for the layer, *Initial Selection...* was chosen. Al-

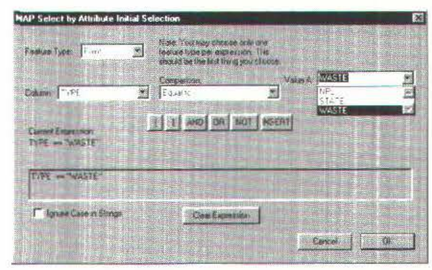

Figure 5. Attribute Selection Menu

though the user may enter an expression directly, pull-down fields simplify the task of creating an expression by using the attributes attached to the imported file. Once the *Current Expression:* included the necessary equation, *INSERT* was chosen transferring the formula to the recessed "expression area." Clicking *OK* completed the operation and returned the user to the document with the specified items selected (FIGURE 6).

For map construction, the selected elements can be modified for the cartographic presentation. It was found that cloning and moving the selection to a new layer allowed the user to keep the original imported file unaltered for further queries and created a buffer for unforeseen error (FIGURE 7). Once the map was completed, the original layer was deleted. In addition to the

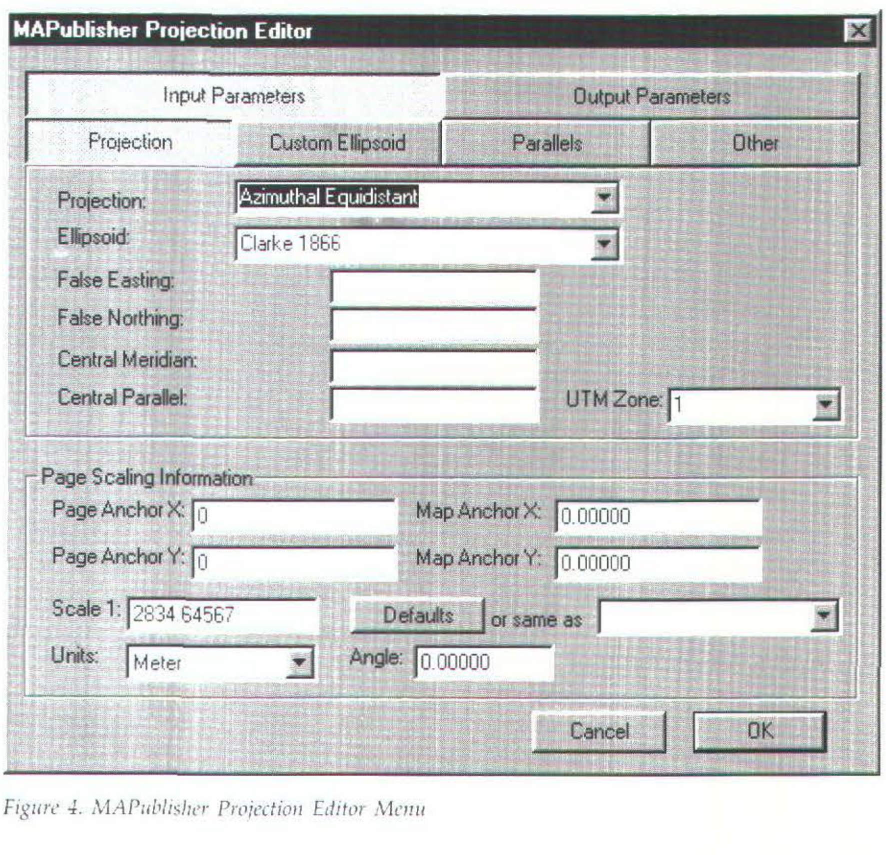

Figure 4. MAPublisher Projection Editor Menu

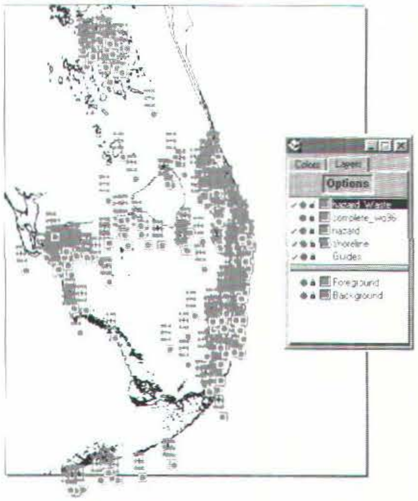

Figure 6. Text Elements Selected

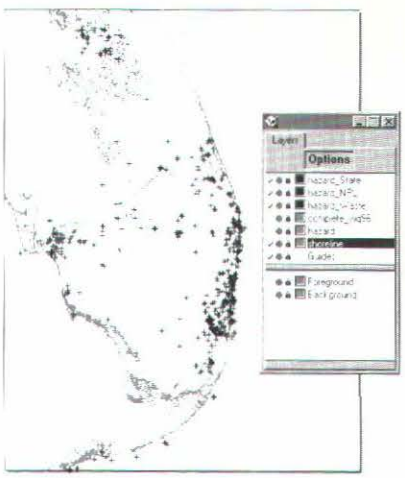

Figure 7. Converted Path Shapes

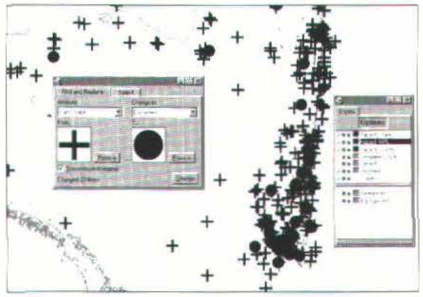

Figure 8. Find and Replace

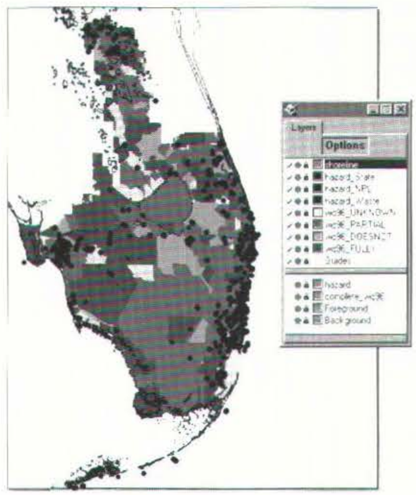

Figure 9. Completed Import

above technique, the efficient *MAP Legend* feature can separate elements while assigning legend information and color based on attributes.

MAPublisher imports GIS lines directly as vector line work; however, point symbols are imported as text plus signs. Freehand 7 can easily change the text to path shapes if these steps are followed:

Select all of the text [*Ctrl A*] and convert to paths [*Ctrl Shift P*]. Select one of the converted path shapes and copy it to the clipboard [*Ctrl C*]. From the *Edit* menu select *Find And Replace*, then choose *Graphics…* [*Ctrl Alt E*]. The *Attribute:* should be set to *Path Shape* and *Change In:* should be set to *Document*. Clicking *Paste In:* under *From:* inserts the converted plus sign shape into the white box. Return to the document leaving the *Find And Replace* menu open by clicking anywhere in the document window. Create a path shape (a closed path circle polygon was used for this example) on a new layer and copy it to the clipboard. Return to the *Find And Replace* menu and *Paste In:* the path shape for the *To:* field. Clicking on *Change* executes the replacement (FIGURE 8). *Note: any unlocked layer containing the element to be changed will be affected. The registration point for these elements is different in Freehand and Illustrator. In Freehand, it is the upper-left corner, while Illustrator uses the lower-left corner.*

The above steps were repeated for both imported coverages resulting in eight layers of discrete data (FIGURE 9). Once satisfied with the import, polygons were filled, line weights were changed and all of the layers grouped in preparation for refit to the atlas basemap. Due to the close fit of the imported layers to

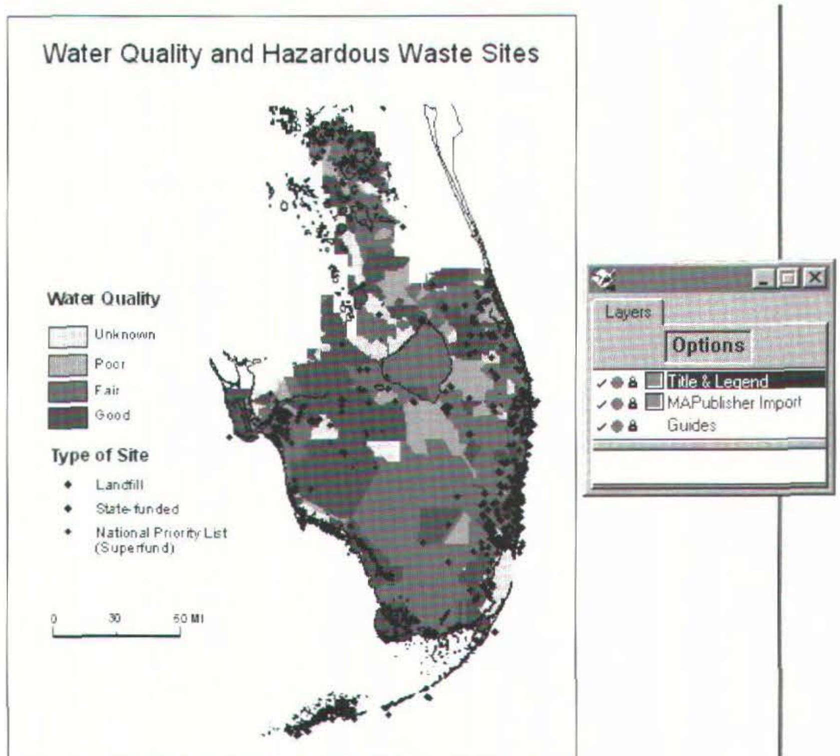

Figure 10. Final Map

the standard basemap for the *WRAF*, it was manually resized. Title, scale and legend were added to the map to complete the graphic (FIGURE 10).

Conclusion:

While MAPublisher did not directly affect the final look of the published maps in the atlas, it proved to be invaluable in converting the large quantities of data received for the preparation of maps into a useable form. The final maps are primarily the result of cartographic design decisions and the functions of the graphics software, but MAPublisher contributed significantly in several ways. First, the final printed maps are much more accurate in the geographic location of features due to the use of detailed GIS data. Second, the ability to take data sets from multiple sources and re-project them to a common projection allows the cartographer to combine layers and create custom maps. Finally, the time and cost savings from using this alternative method were essential to the completion of the project in a timely manner. In many instances, the alternative would have been to take printed output from the GIS, manually trace the line work in a more generalized form, scan the image, and retrace the line work in Freehand.

The utilization of MAPublisher for this project and the techniques that were developed that led to the production of final printed color maps has enhanced the ability of FREAC cartographers to produce high-quality maps for publication that are more accurate and more cost effective. More information about MAPublisher can be found on the website: http://www.avenza.com.

Note: Full screen versions of the graphics can be found at http://128.186.177.25/article.html

map library bulletin board

The Louisiana State University Cartographic Information Center

John M. Anderson
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The Louisiana State University Cartographic Information Center (CIC) is a significant research resource in the Gulf South region. The Center's collection containing over 280,000 maps and 81,000 aerial photographs makes it the largest map collection in Louisiana and ranks it among the larger academic map libraries in the United States. In addition to the many maps and aerial photographs, the collection includes several regionally unique cartographic resources which are available to the University community, state and local agencies, business and private patrons, as well as patrons from around the world.

The Cartographic Information Cen-ter is funded and staffed by the De-partment of Geography & Anthropology and is administratively and physically separate from the LSU Libraries. The CIC collection is comprised of materials in two categories distinguished by ownership. The majority of the material in the collection was acquired by LSU geoscience departments and is now owned by the Department of Geography & Anthropology. Additionally, the CIC houses materials deposited by the Army Mapping Service and the Federal Depository Library Program.

Although the Cartographic Information Center dates its founding to 1960, the collection is the product of both a broad scope of current scholarship and the rich seventy-year history of geoscience research at LSU. The Department of Geography & Anthropology collection reflects the department's teaching and research focus by concentrating on acquiring maps depicting historical and current Louisiana, the Gulf South, Latin America (with particular emphasis on Mexico), East Asia, and Europe. The specific research subjects supported by the collection include historical, cultural, economic and physical geography, anthropology, coastal and fluvial geomorphology, and geology. The regionally unique materials in the Department collection include the largest collection of original Louisiana Sanborn Fire Insurance maps outside of Washington, DC, the most complete set of historic U.S. Coast & Geodetic Survey hydrographic and topographic charts of the Louisiana Gulf Coast housed in the region, copies of historic maps depicting Louisiana, and historic aerial photographs of Louisiana dating from the 1930s to the 1980s.

Among the unique materials covering areas outside of Louisiana is a nearly complete set of original U.S. Geological Survey topographic quadrangle maps printed before 1940. In addition to maps of the United States, the scope of geoscience research at LSU over the past seventy years has brought materials depicting areas outside of the U.S. to the CIC. One example is a collection of over 3000 large scale (1:50,000) topographic maps of Mexico which provides over 96% coverage of the country. In addition to cartographic materials, the CIC houses the Dr. Robert C. West Latin American photograph collection containing over 6,000 black & white photographs and the Dr. Robert C. West Slide Collection of over 10,000 slides from around the world.

Complementing the material amassed by the geoscience departments are the Army Mapping Service depository material from the

1950s and 1960s and the current Government Printing Office Federal Depository Library Program (FDLP). The current FDPL material is located in the CIC as provided in the Separate Housing Agreement with the Regional Depository Library located in the LSU main library. The combination of the Army Mapping Service maps and the current FDLP arrivals provides world wide medium scale topographic map coverage as well as small to large scale map coverage of the United States.

The Cartographic Information Center operates as a closed-stacks library. The staff consists of one full time professional assisted by a 1 Full Time Equivalent student staff who retrieve materials in response to patron requests. In calendar year 1997 the staff served 723 walk-in patrons who requested the retrieval of a total of 1120 maps and 658 aerial photographs. Other patron services include locating and recommending digital data sources, geographic names research, and suggesting map vendors for private purchases. These service requests are received from walk-in patrons as well as via telephone, fax, mail, and e-mail.

In addition to providing daily patron service, the Cartographic Information Center staff is working to overcome problems common to many map libraries such as inadequate space, the need for retrospective cataloging, and preservation. As with other map libraries, the most pressing problem is inadequate space. The recently implemented weeding program designed to remove duplicate out-of-scope materials has barely kept pace with normal acquisitions. Naturally, once the weeding is completed, normal acquisitions will soon fill the recently available space. Additionally, the acquisition of several large research collections is pending until additional space is available. It is hoped that additional space will be acquired in the next three years.

In general, access to collection materials is primarily provided through index maps for series, while other local finding aides are consulted for individual maps. In addition, the FDLP materials are piece-level cataloged in the LSU Libraries LOLA online catalog available at http://www.lib.lsu.edu/databases/lola.html. The Department of Geography & Anthropology collection materials are classified and filed using a locally developed system. An effort is underway to create electronic databases to improve access to the departmental material. Completed databases are available locally for the Dr. Robert C. West Latin American Photograph Collection, as well as for the map holdings depicting Louisiana, Mexico, and the West Indies. The work on databases for the Dr. Robert C. West Slide Collection, and for maps depicting the United States is underway. The pre-1940 U.S. Geological Survey topographic quadrangle map indexes were completed in 1997.

Because the material in the Department of Geography & Anthropology collection results from the long history of LSU geoscience teaching and research, these materials are often old, fragile, and require preservation. In the past, original maps as well as copies of historic maps were acquired. As a result, map materials in the collection range from acetate-based film negatives to fragile newsprint. Additionally, the bulk of the collection is housed in acidic containers. A recently completed major preservation project involved the transfer of historic U.S. Coast & Geodetic Survey chart images from decomposing acetate film negatives to stable mylar. Currently, an ongoing preservation effort is underway to prevent daily wear on fragile maps by removing the maps from the general collection, rehousing them in pH-buffered containers, and placing them in less trafficked drawers.

In addition to the daily map library duties of patron service and processing acquisitions, and the long term rehousing, retrospective cataloging, and preservation efforts, the CIC staff is promoting awareness of the Cartographic Information Center's collection through tours, class presentations, and the World Wide Web. The Center's web site, *www.cadgis.lsu.edu/cic/*, was established in November 1995 to provide an overview of the holdings. Although the majority of the CIC holdings are not in an online catalog, the web site does list the CIC's significant special collections and map series. When the map database for a specific area is completed, a paragraph describing the map holdings is added to the web site. In addition to the descriptive paragraphs and map series listings, a complete list of Louisiana historic aerial photographic coverage by parish and year is provided. A companion list of the CIC's holdings of aerial photomosaics by county and year depicting states other than Louisiana is also available. Finally, in order to illustrate the aerial photograph collection's scope, six representative aerial photos taken of the LSU campus from the 1930s to the 1980s are on the web site.

The Cartographic Information Center is located in room 313 Howe-Russell Geoscience Complex, LSU Campus, Baton Rouge, LA 70803 and is open to the public from 8:00 a.m. to 4:30 p.m. weekdays except University holidays.

The University of Iowa's Map Collection

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Government Publications Department and Map Collection
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The University of Iowa's Map Collection is the largest map collection in Iowa, with more than 176,000 sheet maps, as well as: copies of Sanborn fire insurance maps for more than 1,000 Iowa cities from the 1870's through the 1930's, either on paper or microfiche; Iowa county atlases for the period from the 1870's to the 1930's on microfilm; over 600 Iowa plat books; and more than 100,000 aerial photos of Iowa counties, for various years since the 1940's. Although strongest in Iowa and Midwestern materials, the collection is international in scope and subject coverage is broad, excluding only geologic maps, which are collected at the Geology Library.

Until approximately three years ago, there were no electronic cartographic products in the Map Collection. When I joined the collection in 1995 as half-time Map Librarian, I brought with me an interest in desk-top mapping capabilities. I had worked with federal documents for many years and knew of the wealth of numeric data in the documents department. I had also received training in 1992 on ArcView as part of the ARL / GIS Literacy Project, and had been using a stand-alone copy of ArcView in the Government Publications Department. Thus, the Map Collection began acquiring cast-off CD-ROM drives from other library departments and some fairly simple CD-ROM mapping products (e.g., Map-Expert, Proximity). The Map Collection still did not have any hardware to run higher end mapping programs, until a series of events changed our situation for the better.

First, the library was "wired" in the spring of 1997, enabling Map Collection machines to access the outside world. Then with the assistance of supportive library administrators, we utilized library development funds, money from the library-92s collection development general fund, some of my own map collection funds, plus a donated CPU from another library on campus, and were able to purchase very adequate hardware to run ArcView 3.

At that point, ArcView was relocated from documents to the Map Collection to run on the new machine. Lastly, the Map Collection obtained funding in late 1997 for two more desktop mapping workstations through funds designated by the University's Office of the Provost for instructional technology enhancements. Thus, by the end of 1998, the Map Collection will be running desktop mapping software on three networked machines in the Map Collection-92s reading room. Because of the networked environment, the machines will be linked to each other and to a color laser printer also purchased with the technology enhancement funding. We can also explore additional library access for ArcView, since we have a library site license for ArcView.

I have consciously used the phrase "desktop mapping," rather than GIS in this article. At this point, the goal of placing these machines and software in the Map Collection is to give patrons access to higher-end mapping tools to which they otherwise would not have had access. The University of Iowa has several true GIS laboratories on campus, located in academic departments, where students enrolled in general education / introductory classes can utilize various GIS software products. When many of these students finish taking these types of courses in geography, etc., they will not have access to the departmental labs and to electronic mapping capabilities in general. After speaking with professors, students, and other librarians at ALA and elsewhere, it seemed more useful to focus this beginning service in the Map Collection toward those students (and faculty) whose main needs can be met by mapping programs such as ArcView and Maptitude.

As you can see, the path to getting the three machines was not clear-cut, the results came to us in phases, but the focus audience was always the same. The administrators at the University Libraries are very supportive of having desktop mapping capabilities in the Map Collection. We had earlier made larger requests to university offices for machinery and software for this service and had always been rejected. Thus, the piece-meal approach was begun, and it paid off. Now time must be devoted to writing policies, creating templates and pre-designed maps, hunting for tutorials, grappling with levels of service, finding staff time for this new service, and even figuring out how these large machines will fit into the space available. But had we not been willing to pre-define our audience and to advance our cause gradually, I believe we would still be waiting for our first desktop mapping station in the Map Collection.

NACIS news

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NACIS Board Meeting
January 10, 1998
Lexington, KY

Present: Andrews, Baruth, Brewer, Chu, Crampton, Gilmartin, Krejcie, Meacham, Minton, Nelson, Patterson, Peschel, Peterson, Stoll, and Thorne.

Michael Peterson recognized Pat Gilmartin as the newly-elected President of NACIS and turned over the meeting to her. Gilmartin called the Board to order and welcomed the newly-elected officers: Cynthia Brewer (Vice President), and James Minton (Secretary) and new Board members: Greg Chu, Elizabeth Nelson, Jim Meacham, and Jeremy Crampton. Continuing Board members are: Peterson, Thorne, Patterson, Krejcie, and Stoll. Sona Andrews continues as Treasurer. Gilmartin also thanked Peterson for his hard work as immediate past President, Craig Remington for his work as Secretary and the out-going Board members for their service: Jim Anderson, Barbara Buttenfield, and Glen Pawelski. NACIS executive officers are: Sona Andrews, Susan Peschel, and Chris Baruth.

Cartographic Perspectives

CP Editorial Board reported on the progress of searching for a new editor. They recommended disbanding the three-year rotation. A guest editor would be responsible for one issue per year. Mike Peterson volunteered his name as editor for a three year term effective Fall/Winter 1998. With Peterson absent, the Board moved, seconded, and discussed the appointment. The vote was unanimous in support of Peterson to assume the role of Editor.

Further CP News: Jim Ackerman and Jeremy Crampton have already volunteered to be future guest editors. Joanne Perry will assume role of Book Review Editor with assistance. Several names were suggested for CP Editorial Board. Buttenfield offered to send flyers to encourage contributions to CP. Motion was made, seconded, discussed and approved by the Board.

It was noted that CP is getting very close to the page limits for consideration of moving to Perfect Binding. This move would cost an additional $120.00 for every additional four pages.

Meeting Site For Year 2000

An open discussion was held proposing several potential sites for NACIS 2000. Members are encouraged to propose host institutions and sites and offer them to the Board for consideration. Submitting sites should consider a host department such as geology, geography, or GIS lab. Other issues to consider are hotel and air fare costs. Cities suggested were: Las Vegas, Cleveland, Omaha, Kansas City, Portland or Eugene, OR, San Diego, Knoxville, and Saratoga Springs, NY.

Membership Committee

Issue was raised concerning "regular student," "subscription," and "affiliate" memberships. Other issues relating to membership: The establishment of a Bulletin Board (electronic), mailings to GIS, carto special interest groups (such as URISA).

WEB Committee

Jeremy Crampton offered to chair a Web (WWW-type) Committee. Such a site would cost about $25 per month. Crampton and the Board will explore this issue further. Baruth offered to work with the Committee and the possibility of moving UWM's "Leardo" to the Web. Parts of the pages could include: NACIS organization / officers, annual meetings, parts of CP. The Board will re-assess at the spring meeting.

Spring Board Meeting

Peterson noted that the experience with a telephone conference call for the Board meeting did not work well. Gilmartin asked for suggested meeting sites. Atlanta, Chicago, Las Vegas, and Dallas were offered. Gilmartin will determine best site and notify members in early 1998.

New Business

Rowles mentioned an idea of giving plaques to students who assist in the annual conference. She also noted that AAG meets March 24th-29th, 1998.

Submitted,
Jim Minton
NACIS Secretary

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from the NACIS President
continued from page 1

board. In reality, Mike had been an obvious choice all along, but it just took a little time to convince him. Mike has done an outstanding job for a number of years as chair of the editorial board, and I have no doubt that he will continue his exemplary work as editor. I would like to thank Mike for accepting this responsibility and to remind everyone else that we can make his life-as-editor easier by sending him more good manuscripts to consider for publication in *CP*.

The next reason I can enjoy serving as president of NACIS is the tremendous job done by our Executive Officers at UW-Milwaukee: Chris Baruth, Sona Andrews, and Susan Peschel. NACIS members may get tired of hearing this same refrain from every president, but the reason we sound like a broken record is because these three make the president's job such a ... well, ... a pleasure. They maintain our records and mailing lists, collect dues, manage many of the arrangements for the annual conference, and handle innumerable other details. The continuity and experience provided by Chris, Sona, and Susan form a strong infrastructure for NACIS which is invaluable to its officers, board members, and membership.

After a well-attended and informative annual meeting in Lexington last fall, we are looking forward to getting together again this year in Milwaukee (October 7 - 10). Dr. Cynthia Brewer is Vice President and Program Chair this year. If you have questions or suggestions about the annual conference, you can reach Cindy at cbrewer@essc.psu.edu (or at the Department of Geography, Penn State University, University Park, PA 16802). The usual Call for Papers and details of the meeting will be mailed out later this spring, but it is not too early to be thinking about attending and participating in the meeting.

This year's annual meeting will be preceded by a full-day symposium on the topic of "Maps and Minds: A History of Cartography in Geography Education." Organized by James R. Ackerman of the Hermon Dunlap Smith Center for the History of Cartography at Chicago's Newberry Library, the symposium will feature six to eight invited speakers who will examine the development and use of maps in Western education and publications from the sixteenth through the twentieth centuries. This symposium, which has been several years in the planning, constitutes a rare opportunity to reflect on the interaction between cartographic publication and societies' educational priorities. Look for details in the Call for Papers for the annual meeting and on our website at www.nacis.org.

Yes, 1998 is a good year to be president of NACIS, mainly because of the admirable support provided by current and past officers of the organization. I invite you to join NACIS (if you are not already a member), renew your membership (if you are late with your dues), and participate (if you have been lurking in the wings). I can assure you that you will enjoy the results.

Pat Gilmartin
President, NACIS

submissions

The editors of *Cartographic Perspectives* welcome manuscript submissions. Please follow these guidelines.

FEATURED PAPERS

Each issue of *Cartographic Perspectives* includes featured papers, which are refereed articles reporting original work of interest to NACIS's diverse membership. Papers ranging from theoretical to applied topics are welcome. Prospective authors are encouraged to submit manuscripts to the Editor. Papers may also be solicited by the Editor from presenters at the annual meeting and from other sources. Ideas for special issues on a single topic are also encouraged. Papers should be prepared exclusively for publication in *CP*, with no major portion previously published elsewhere. All contributions will be reviewed by the Editorial Board, whose members will advise the Editor as to whether a manuscript is appropriate for publication. Final publication decisions rest with the Editor, who reserves the right to make editorial changes to ensure clarity and consistency of style.

REVIEWS

The Book Review Editor, Joanne M. Perry, will solicit reviews of books and atlases. Publications are to be sent directly to Joanne M. Perry, Map Librarian, The Valley Library - 121, Oregon State University, Corvallis, Oregon 97331-4501 or perryj@ccmail.orst.edu. Reviews of maps and mapping software will be solicited by the Editor of *CP*. Prospective reviewers are invited to contact the Editor directly at geolib@unomaha.edu.

CARTOGRAPHIC TECHNIQUES

Articles that concern all aspects of map design and production are solicited by the Cartographic Techniques Editor, James E. Meacham, Director, InfoGraphics Lab, Department of Geography, University of Oregon, Eugene, OR 97403-1251 or jmeacham@oregon.uoregon.edu.

MAP LIBRARY BULLETIN BOARD

The Map Library Bulletin Board Editor, Melissa Lamont, solicits reports on the current status of map libraries. Submissions are to be sent directly to Melissa Lamont, Data Library, McLean Laboratory, Woods Hole Oceanographic Institution, WHOI Mail Stop 8, Woods Hole, MA 02543 or mlamont@whoi.edu.

TECHNICAL GUIDELINES FOR SUBMISSION

Literature cited should conform to the Chicago Manual of Style, 14th ed., University of Chicago Press, Chapter 16, style "B." Examples of the correct citation form appear in the feature articles of this issue. Authors of Featured Papers should submit four printed copies of their manuscript for review directly to Michael Peterson, Editor of *Cartographic Perspectives*, Department of Geography / Geology, University of Nebraska at Omaha, Omaha, Nebraska 68182. Manuscripts are reviewed by three referees. The Editor will contact all authors to notify them if their paper has been accepted for publication and if revisions are necessary prior to publication. The following technical guidelines should be followed for all accepted manuscripts (these guidelines also apply to book, map, and software reviews).

Material should be submitted in digital form on 3.5" diskettes. Please send a paper copy along with the disk. Text documents processed with Macintosh or Windows software, such as *WordPerfect or MS Word*, are preferred.

PostScript graphics generated with *Adobe Illustrator* or *Macromedia FreeHand* for the Macintosh / Windows or *Corel Draw* for Windows computers are preferred, but generic PICT or TIFF format graphics files are usually compatible as well. EPS format graphics should include only the graphic with no figure caption. Graphics may be submitted on disk, placed on an FTP site, or sent to ftpnt.freac.fsu.edu. Manually produced graphics should be no larger than 11 by 17 inches, designed for scanning at 600 dpi resolution (avoid fine-grained tint screens). Continuous-tone photographs will also be scanned.

Text and graphic files should be sent to: Mr. James R. Anderson, Asst. Editor, FREAC, UCC 2200, Florida State University, Tallahassee, FL 32306-2641; (850) 644-2883, fax: (850) 644-7360;
email: janderso@mailer.fsu.edu

Special thanks to the following individuals who have made donations to *Cartographic Perspectives*.

Kevin Byrne
William Gennetti
John Hutchinson
E.L. Lanzer
Joseph Poracsky
David Woodward

NEW NACIS WEB SITE
www.nacis.org

NACIS membership form

North American Cartographic Information Society
Sociedad de Información Cartográfica Norte Americana

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Organization / Afiliación profesional: ______________________

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Make all checks payable to/
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P.O. Box 399
Milwaukee, Wisconsin 53201

***Membership fees include subscription to *Cartographic Perspectives*.**

The North American Cartographic Information Society (NACIS) was founded in 1980 in response to the need for a multidisciplinary organization to facilitate communication in the map information community. Principal objectives of NACIS are:

§ to promote communication, coordination, and cooperation among the producers, disseminators, curators, and users of cartographic information;

§ to support and coordinate activities with other professional organizations and institutions involved with cartographic information;

§ to improve the use of cartographic materials through education and to promote graphicacy;

§ to promote and coordinate the acquisition, preservation, and automated retrieval of all types of cartographic material;

§ to influence government policy on cartographic information.

NACIS is a professional society open to specialists from private, academic, and government organizations throughout North America. The society provides an opportunity for Map Makers, Map Keepers, Map Users, Map Educators, and Map Distributors to exchange ideas, coordinate activities, and improve map materials and map use. *Cartographic Perspectives*, the organization's Journal, provides a mechanism to facilitate timely dissemination of cartographic information to this diverse constituency. It includes solicited feature articles, synopses of articles appearing in obscure or non-cartographic publications, software reviews, news features, reports (conferences, map exhibits, new map series, government policy, new degree programs, etc.), and listings of published maps and atlases, new computer software, and software reviews.

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