A Review of Digital Geographic Information Standards for the State/Local User

Eduardo A. Fernandez-Falcon, James R. Strittholt, Abdulaziz I. Alobaida, Robert W. Schmidley, John D. Bossler and J. Raul Ramirez

Abstract: *Over the past two decades, the use of computer mapping systems (GIS/LIS) has become commonplace at both state and local levels in the United States. Along with this technological revolution has come the need for the development and adoption of standards directed at the production, use and sharing of digital geographic databases. This paper accepts the taxonomy of standards as presented by Croswell and Ahner (1990), reviews the standards needs of state and local government agencies, and discusses four user-design standards topics which are important for the effective use of GIS technologies at state and local levels. The four topics considered include: geodetic control networks and integration of surveying data into GIS, provisional spatial databases, metadata and property assessment.*

Data and information are clearly among the most valuable resources in modern societies. Today, estimates indicate that over 80 percent of the ever-growing quantity of data and information used in the United States is spatially referenced, or geographic (Huxhold 1991). Government agencies at the federal, state and local levels, utilities, and other businesses spend billions of dollars annually to produce and maintain these geographic data and information. With the continued development of powerful computers and a variety of accompanying geographic information systems (GIS), the use of digital geographic information has become commonplace, and its use continues to spread, particularly among state and local governments.

While computer-mapping technologies continue to evolve, the growing body of geographic data users have been able to identify problems associated with the use of new technologies and are now better equipped to accurately predict future trends and needs. As a result, the demand for standardization in order to use GIS is commonly heard. Perhaps the most powerful driving force behind the demand for standardization at various organizational levels is the desire by users to *share* data and information. The digital databases assembled for these systems make up the largest part of the cost of maintaining a GIS system (Moyer *et al.* 1991). Being able to share geographic data dramatically reduces cost to all users, and allows for more timely access to valuable information. Gurda (1991) would add that the need to simplify the operation of GIS is another important reason to develop and adopt standards.

The topic of standards as applied to production, use and sharing of digital geographic information is important and complex. Tom (1988) believes that the ultimate success of mapping technologies hinges on the widespread integration of computer technologies (hardware and software compatibility), and he contends this capability is largely dependent upon the adoption of effective standards. While Tom may be entirely correct in his assessment of GIS computer technology standards, Croswell and Ahner (1990) present a more comprehensive analysis of GIS standards by proposing a taxonomy that subdivides digital geographic information into six primary categories to which standards can apply. This paper first examines a particular (Croswell and Ahner 1990) standards taxonomy, attempts to identify the standards most important to the state and local user, and

Eduardo A. Fernandez-Falcon is a Ph.D. candidate in the Dept. of Geodetic Science and Surveying at The Ohio State University, and a graduate research assistant at the Center for Mapping.

James R. Strittholt is a Ph.D. candidate and a graduate research assistant at the Center for Mapping, The Ohio State University.

Abdulaziz I. Alobaida is a Ph.D. candidate in the Dept. of Geodetic Science and Surveying at The Ohio State University, and a lieutenant colonel in the Saudi Arabia Army.

Robert W. Schmidley is a Ph.D. candidate in the Dept. of Geodetic Science and Surveying at The Ohio State University, and a graduate research assistant at the Center for Mapping.

John D. Bossler is director at the Center for Mapping, and professor at the Dept. of Geodetic Science and Surveying at The Ohio State University.

J. Raul Ramirez is a research scientist at the Center for Mapping, and adjunct professor at the Dept. of Geodetic Science and Surveying at The Ohio State University.

then discusses four key areas of standardization that directly affect these state and local GIS-user concerns.

Taxonomy of Standards

Standards have been defined as, "a category of documents whose function is to control some aspect of human endeavor" (Sullivan 1983). Standards control conditions, aspects, or behavior of practically everything on earth. He reminds us that there is need for more detailed knowledge of the workings of standards and their significance to society. Sullivan (1983) states four important values of the development and use of standards. Standards: (1) educate both manufacturers and purchasers about a product; (2) promote the conservation of manufacturing by encouraging better tooling, more careful design, and more precise production controls; (3) simplify any process making it more cost effective; and (4) clearly identify hallmarks of quality forming a basis by which to certify.

With some developing technologies, new items being added to the marketplace are developed simultaneously with new controls and guidelines (active standards). In other cases, standards are written later in the development of new items to solve problems created by the evolving use of the new technologies (reactive standards). This is the case for GIS.

Whether active or reactive, standards are an important means for bridging communication gaps, and the effectiveness of any standard depends upon the value of the standard as perceived by a sufficient number of people who are willing to observe it (Sullivan 1983). In addition, standards can also be viewed as a double-edged sword: the lack of standards can result in chaos, yet premature, excessive or outdated standards can result in the stifling of innovation and progress in the production and use of the technology.

If Moyer and Niemann (1991) are correct in calling for standardization in GIS at the state and local levels at this time, answers are needed for key questions. The most important one: **What standards are important to state and local governments?**

To help examine this question, we must first accept a working taxonomy for looking at digital geographic information standards. We have chosen the taxonomy proposed by Croswell and Ahner (1990) since it is the most widely referenced. They subdivide and describe six categories of geographic information computing standards:

1) **Hardware and Physical Connection Standards.** These are standards that pertain to the physical connection and cabling of hardware devices.
2) **Network Communication Standards.** Involves the development of protocols for the transfer of data and information from one computer system to another.
3) **Software Standards.** Focuses on the compatibility of operating systems for the various vendor platforms.
4) **Data Presentation and User Access Standards.** Includes standards that impact the actual presentation and display of data in a GIS system.
5) **Data Structure Standards.** The logical structures of the data stored in the computer are the focus of these standards.
6) **User Design Standards.** These include a wide range of standards issues that influence the design and implementation of GIS including attribute data schemes, coding rules, map accuracy, quality control and map design criteria.

This taxonomy suggests that the topic of digital geographic information standards is not a simple one, and one that covers a number of technological and institutional issues. Using this taxonomy as a framework, we will attempt to answer the question: *What type of standards are of interest to the state and local government user?*

State/Local Government Standards Needs Assessment

We attempted to answer the question of state/local government interest in standards by reviewing three sources, and categorizing the results according to the taxonomic headings developed by Croswell and Ahner (1990). One source of information was the Subcommittee on Classification and Standards of the Wisconsin Land Records Committee published in 1986 in the form of a "summary of concerns." A second source of information is the result of a 1990 survey on state GIS standards conducted by the Mississippi Institutions of Higher Learning, Center for Policy, Research and Planning. The final source came from the GIS Professionals Survey conducted by Croswell and Ahner (1990) themselves.

Wisconsin Lands Record Committee

This committee included a majority of state and local government representatives. They identified seven key concerns about standards. Table 1 lists the seven issues identified by this subcommittee, followed by our attempt to categorize each one as to which of the six Croswell and Ahner (1990) headings best applies.

Mississippi Survey

Paul Davis of the Mississippi Automated Resource Information System (MARIS), Mississippi Institutions of Higher Learning and Bruce Davis and Ralanda Camper of the Center for Spatial Data Research and Applications, Jackson State University summarized the results of their survey in a presentation at the 1991 URISA Con-

TABLE 1. Seven Most Important Concerns of the Wisconsin Subcommittee on Classification and Standards.

Standards Issue	Category
1) Description of data file content.	6
2) Data index catalog.	6
3) Identification of geographic reference systems.	6
4) Data exchange including computer language formatting.	1–3
5) Basic data elements.	6
6) Specific quality controls.	6
7) Labeling of file combinations.	6

ference. The survey was directed to key GIS contacts in 48 states. Thirty responses to the survey were received.

One of the questions in the Mississippi Survey dealt with the categories or components of GIS standards that states are contemplating. The list of GIS standards components was developed from the one employed in the Croswell and Ahner survey. Respondents to the Mississippi survey were asked to indicate the most important standards from this list for their state's GIS structure or activities. The five more important standards are presented in Table 2, along with our categorization.

GIS Professionals Survey

Croswell and Ahner (1990) sent a mail survey to numerous, experienced GIS professionals, and asked them to rank a series of standards issues as not critical or critical. Table 3 contains two selected results from this survey: the three most critical standards concerns, and the three standards areas receiving the least attention from the GIS industry.

Needs Summary

While the results for both of the state information sources are somewhat different (Tables 1 & 2), they do share a common theme. Both the Wisconsin and Mississippi perspectives identify the computer technology standards as an issue (Categories 1–3), but both strongly indicate the need for standards that pertain to user design (Category 6). They also identify communication, whether through a state-wide catalog (Wisconsin), or clearly defined data dictionaries (Mississippi), as an important component of standards consideration.

The GIS "professionals survey" results of Croswell and Ahner (1990) offer an interesting contrast to the previous two surveys. Here, a wide range of GIS professionals from different institutional backgrounds were asked for their opinions about GIS standards. The results in Table 3 clearly demonstrate a different view of the same technological field as shown in Tables 1 and 2. These results indicate a likely bias of survey respondents for identifying and solving the more technical standards issues dealing in large part with computer problems, rather than the institutional problems that are at least equally difficult.

TABLE 2. State of Mississippi Survey Top Five Standards Concerns

Standards Issue	Category
1) Map accuracy guidelines.	6
2) Translation of data exchange.	1–3
3) Data classification and coding.	6
4) Data dictionaries.	6
5) Data quality assurance.	6

Discussion

Obviously, the problems facing GIS standardization will require cooperative efforts by all interested parties such as computer vendors, academia, federal agencies and state/local GIS groups. Developing the technological and institutional solutions to the various digital data and information problems will require serious commitment by all to forge new relationships and accept fundamental changes to traditional work patterns and methods. Standardization efforts should proceed quickly in order to facilitate data sharing, but thoughtfully, in a climate of cooperation.

The different members of the community using this rapidly emerging technology will hopefully contribute to this effort in the areas they feel most capable. Based on the survey results reviewed in this paper, it is clear that user design standards are perceived as the most important standards category to the state and local GIS

TABLE 3. Partial results of GIS Professionals Survey Conducted by Croswell and Ahner (1990)

Standards Issue	Category
A) Most Critical	
1) Translation and data exchange.	1–5
2) Vendors development of open systems.	1–2
3) Database update and maintenance.	6
B) Least Attention by Vendors	
1) Data quality.	6
2) Quality assurance process.	6
3) Geographical analysis index.	6

user, and perhaps is the area of GIS standardization where this group should focus its attention and efforts. Narrowing the field of problems needing consideration helps somewhat here, but so many problems exist under the user design heading that a gargantuan task still remains. Clearly, the results of our review indicate that the needs are focused on issue 6 of Croswell and Ahner's taxonomy. We believe therefore that a new taxonomy of GIS standards should be developed to facilitate our understanding of these issues. The scope of this paper does not allow us to address these user design problems.

Four User Standardization Concepts

We can offer four ideas that could contribute to the GIS user design standardization in a meaningful way. While somewhat arbitrary, they are issues the authors are familiar with and ones that we believe are important. The issues we put forth focus primarily on solving important **operational** problems for state/local agencies. The four topics developed include:

1) Geodetic Control Networks and Integration of Surveying Data into GISs
2) The "Provisional" Spatial Database
3) Metadata
4) Property Assessment.

1. Geodetic Control Networks and Integration of Surveying Data into GISs

Geodesists and surveyors commonly recommend high-accuracy network control densification for GIS, but establishing and then maintaining a strong geodetic network control with high standards in terms of precision and monumentation have been a problem particularly for local governments (NRC 1983). With limited resources, local government agencies are often unable to establish such a geodetic network, and under current economic conditions this pattern seems likely to continue into the foreseeable future. The cost of a geodetic control network is a function not only of the observations, but the corresponding monumentation. Even with the availability of low-cost, high-tech tools for geodetic positioning such as GPS (Global Positioning Systems), the procedures recommended by the NRC (1983) still require expensive monumentation. In the past, monumentation was the least expensive item in setting geodetic control points, but today, GPS technology has evolved in such a way that almost instantaneous position determinations are possible, and therefore, the construction of monuments take a bigger portion of the total project cost. It is estimated that new monument setting costs between $200 and $500 each depending on point location, type of material and number of monuments (CEAO 1992). Adoption of GPS technology is now feasible and highly desirable in the local government environment, but the requirement of monumentation and maintenance (NRC 1983) may eventually slow its use.

The lack of a dense control network makes the integration of surveying data (data collected by land surveyors and utility companies) into a GIS a difficult task, with the result being the loss of potentially valuable information. The integration of surveying data into a local GIS can be practically implemented only when sufficient numbers of control points, located closely to each other, allow surveyors to link property surveys to the network under economically and technically acceptable circumstances. Therefore, a compromise solution that provides a dense coordinate reference system at a reasonable cost needs to be found.

An initial step in this direction should be taken by agencies at the local level, which is to realistically specify the maximum accuracy requirements needed for their operations. Research in this area, conducted by the GIS community, will contribute to the multiplication of successful GISs. This research should also address the integration of different data sources within the reference framework. The control network required for local government operations should be consistent with the maximum accuracy required by local surveyors for property surveys. The accuracy of a dense network should be consistent with the requirements for cadastral surveys (Keating 1992). This type of geodetic network will be referred here as "cadastral network." This positional accuracy standard is not likely to exceed one-tenth of a foot according to typical state surveying standards.

As a way to minimize the cost of geodetic network densification, and considering the use of GPS technology, we suggest that "non-conventional" monuments be used that already exist throughout the urban landscape for determination of the "cadastral network." As examples, features such as water hydrants and manhole covers could fulfill these needs. For hydrants, the top bolt can be used to position the GPS antenna and for manhole covers, the geometric center could serve as the control reference. The "center" of these symmetric objects can be estimated to ± 0.05 feet. This kind of "poor accuracy" can be tolerated because GPS errors will not be propagated in the same way as classic methods. The use of such "non-conventional monuments" presents several advantages:

- They already exist
- They are easily recognizable in low-altitude aerial photos, which make them useful for photogrammetric aerotriangulation
- They are numerous in urban areas
- They are accessible, and therefore could be easily and accurately positioned (theoretically in a matter of seconds) using kinematic GPS techniques.

The main argument against the use of these non-conventional monuments would be their lack of stability. However, this factor might easily be neutralized. The high number of available hydrants and manholes per block for example, would allow linkage of the property surveys to many of these non-traditional monuments and, hence, numerous checks on stability without a substantial increase in the surveyors' work.

If such a dense cadastral network is developed, it may be possible to include its use in the current local surveying regulations, with clauses requiring private surveys to be tied to this network (Keating 1992) and submitted to the appropriate agency in digital form. With such regulations in place, surveys required for mortgages, construction permits and other purposes would gradually provide spatial databases of "high accuracy."

As in most of the stages involved in the implementation of a GIS, cooperation in the development of a "cadastral network" and integration of survey data becomes fundamental. The success of this type of approach will be based on several factors: (1) the development of standards to carry out the completion of cadastral networks; (2) the effectiveness of state and local government in setting up new standards for private surveys once the basic control networks are in place; and (3) the dialogue between county government and utility companies that allows for the development of standards for on-ground utility surveys.

Ultimately, the success of the standards specified by state and local governments will depend on their acceptance by the affected parties. Such acceptance could be encouraged by developing an incentive program, and also through participation of survey organizations, utility companies and any other parties involved in the discussions of standardization processes.

2. *The "Provisional" Spatial Database*

The availability of accurate survey data will, in the short term, create some inconveniences when integrated with existing data. Goodchild identifies this problem:

> "However attractive, the concept of GPS as a data source for GIS, and however easy the technical issues of merging the two technologies, in practice, integration presents enormous difficulties. Many of these (difficulties) have to do with accuracy, and in particular the difficulties of merging data of high positional accuracy from GPS with the types of data commonly found in spatial databases. . . ." (Goodchild 1992)

The integration of accurate GPS and survey data, and the improvement of the control networks, would make evident the low quality of some of the existing databases (in relation to their positional accuracy). In general, however, GIS users are often more interested in the completeness of the data than they are in positional accuracy (NRC 1983).

The problem can be illustrated by noting that it is not uncommon to see DLG-3 7.5' (scale 1:24,000) files integrated with TIGER data (scale 1:100,000) together with manually digitized tax maps (variable scale, e.g.: 1:4800). Moreover, geodetic control could be included in the data. These procedures would be technically acceptable if the final product is represented at the smallest scale (1:100,000 in this example), but regrettably, this is often not the case. The lack of a value of "associated accuracy" attached to each database features or to the metadata (see next section), makes the tracking of a particular feature's origin virtually impossible.

Today, the concept that "any data are better than none at all" is widely rationalized. Under these circumstances, it is evident that data integration at different scales will continue to be performed with or without accuracy attributes. We suggest that such databases be considered as "Provisional Spatial Databases." Strictly speaking, all databases are "provisional" because of the constant need for updating. However, state/local government agencies, who are anxious to use and develop GIS at reasonable costs, should develop standards to keep inappropriate data integration and manipulation from occurring.

The adoption of data integration standards and procedures for "provisional databases" should be based upon the development of dense "cadastral networks" and the integration of survey data. The improvement of those databases will be directly linked to the success of capturing highly accurate cadastral data. In this context, existing databases will become meaningful when adjusted within an accurate framework. The adjustment of existing data should be defined by the polygon which contains the entire unit of interest. For example, the adjustment of existing tax maps should be conducted by taking a block at a time and adjusting the available information of a parcel within that block. This approach will allow the adjustment of a limited area every time that new information is added. In other words, the addition of new information within an area will require a sequential adjustment, but only within a specific block (Tamin 1992).

The adoption of standardized metadata structures (see next section) would alert potential users to data quality, but strict standards and procedures within the different agencies of state/local government should be established to limit the degradation of the database and to avoid the production of meaningless or confusing outputs.

The "provisional" character attached to the described databases will gradually disappear when the flow of accurately collected data allow the replacement of all the data which were not referenced to the "cadastral network." Meanwhile, state/local government should develop standards to attach accuracy estimations to the existing data, based on their sources, together with a methodology for assigning weights to the data according to its accuracy. Adjustment procedures should also be standardized to prevent any misuse of the "provisional" spatial databases.

3. *Metadata*

The type of data exchanges and manipulation expected to occur between different agencies within state and local governments, and between local government and private or public organizations, requires the standardization of metadata structures and content within every database. Metadata, simply put, are data about data. More specifically, metadata are the data that describe the data contained in a digital database (e.g., layer content) and information about the database itself (e.g., file locations). This type of information allows the user to evaluate the content, access and eventually, cost of a particular database. Through the analysis of the metadata, potential users are able to accept or reject part or all of a spatial database for the specific task that is to be expected to perform.

Understanding the need for the standardization of metadata content, the Federal Geographic Data Committee (FGDC) sponsored an Information Exchange Forum on Spatial Metadata during June 1992. Soon after that, a draft standard for metadata (FGDC 1992) was developed and it is now being evaluated by potential users. This evaluation process was completed in April 1993, and will lead to the final version of the standards which, in time, will be adopted by federal agencies. GIS vendors will be encouraged to implement these standards, and it could be safely expected that state and local governments will adopt them in view of their usefulness.

For spatial databases used in GIS, convenience and usefulness would be served if the metadata section were "attached" to the database without being part of it, thus making the metadata application independent. In other words, it should not be necessary to activate any database application to be able to read the content of the metadata. In this case, a metadata section could logically precede the actual spatial database. This would allow for the metadata section to be quickly evaluated minimizing search time for critically important information. According to the FDGC draft standard, the metadata would contain:

- an identification section;
- projection, data custodian, access, status and source information together with table definitions and table attributes of the data dictionary/schema;
- source information;
- processing steps;
- data quality; and
- a metadata reference section which describes the currentness of the metadata.

The user-evaluation process will undoubtedly improve the already excellent quality of the suggested standards, and their adoption by federal, state and local government will result in an improved data quality control process, and the rational use of spatial databases.

4. *Property Assessment*

The adoption of GIS technology by county government agencies has originated in many different ways. For some local governments, the use of GIS has become a by-product of the computerization of records and billing systems during the seventies and eighties (e.g., Prince Williams County-Virginia (Phillips 1987)). For others, GIS was adopted as a tool for improving property appraisal procedures (e.g., Franklin County, Ohio). This last purpose suggests immense possibilities if an appropriate set of standards is developed to regulate the input of related data.

The property-appraisal process is not only difficult, but delicate in nature because appraisal is used to fairly distribute the tax burden. This procedure differs greatly among counties across the United States. In general, auditor offices develop tax maps by integrating different types of data. Some tax maps are assembled by using information originating from original property deeds, others use photogrammetric methods (mosaics or orthophotos), and still others use surveying data (originated in subdivision plots, etc). Counties incorporating GIS technology into their affairs usually digitize previously developed maps and integrate them into their databases.

The appraisal process involves several physical characteristics of the property. Some of these are: parcel dimensions and area, parcel location within a block, block location within a subdivision, number and type of existing buildings and their footage, features (e.g., number of bathrooms, number of rooms), type of construction (divided into classes), and use (commercial or private). If properly collected and organized, these types of data can be of enormous benefit to other local agencies (e.g., fire-fighting divisions, planning offices), utility companies and private users.

Therefore, the properties' physical characteristics (some of which were included above for reference purposes only) could be used to develop coefficients that assess their value. When combined with real estate information (minimum and maximum current costs of properties within the same subdivision) those coefficients could effectively assess the property value in a fair and standardized fashion. The information about the physical characteristics of a property could be collected through the use of simple "evaluation tables" to be filed by tax payers at the time of transference, or when construction permits are processed.

The described procedure is primarily drafted for urban areas, but can be extended to rural zones as well. In rural areas, characteristics such as soil quality, water availability, flood risk, and road access can be studied to substitute and add variables to the original urban model.

An additional factor could affect the equity of the assessments: the "physical reality," i.e., the true area, size and/or shape of the parcel could differ from that shown in the tax map, and could also be different from the parcel description appearing in the deed. The analysis of this problem and suggestions for its solution are beyond the scope of this paper, but the reader should be aware of its existence.

Local governments should develop simple and well-designed standards to assess property values based on physical characteristics. This task should be conducted not only by county auditor office personnel, but by any agency with potential interest in these types of data. The elements included in the standards should be such that they fulfill not only the model required by the auditor's office, but those suggested by other related agencies.

Conclusions

The difficult task of setting up GISs in state and local government agencies requires a complete understanding of the value of standards and the standardization process. Lower costs and improved operations will be two of the immediate results of the proper implementation of such a process. This paper reviews a taxonomy of standards and presents a discussion of the areas in which local governments are most interested. User-designed standards are identified as the most important to be defined at a local government level. Based on those needs, the authors expand on four topics of user designed standards: cadastral network and integration of surveying data, the "provisional" database, metadata and data dictionary, and property assessment with an intent to contribute to the understanding of the standardization process.

References

County Engineer's Association of Ohio. 1992. "Surveying and Geodetic Control Guidelines and Recommendations for Local Geographic and Land Information Systems." CEAO, November 7.

Croswell, P. and Ahner, A. 1990. "Computing Standards and GIS: A tutorial." Proceedings of the URISA Annual Conference, Vol. 2.

Davis, P., Davis, B., and Camper, Ralanda. 1991. "State Government GIS Standards: A National Survey." Paper presented at the 1991 URISA Conference, San Francisco, California.

Federal Geographic Data Committee. 1992. "Content Standards for Spatial Metadata (Draft)." USGS.

Goodchild, M. 1992. "GPS as an Aid to Spatial Data Quality: The pluses and Minuses." On Common Ground Conference. April 13–14, Denver, Colorado.

Gurda, R. 1991. "The State's Role in Setting GIS/LIS Standards: Metadata Standards from a State Clearinghouse Perspective." Proceedings of the URISA Annual Conference.

Huxhold, W. 1991. "An Introduction to Urban Geographic Information Systems." Oxford University Press.

Jordan, L. and Star, J. 1992. "A Call to Action: Standards for the GIS Community." *Photogrammetric Engineering and Remote Sensing*. Vol. 58, No. 6, pp. 863–864.

Keating, R. 1992. "Building Accuracy into a GIS." *GIS World*. Vol. 5, No. 5, pp. 32–34.

Moyer, D. and Niemann, B. 1991. "The Why, What, and How of GIS Standards: Issues for Discussion." *URISA Journal*, Vol. 5, No. 2, pp. 10–24.

National Research Council. 1983. "Procedures and Standards for a Multipurpose Cadastre." National Academy Press. Washington D.C.

Phillips, J. 1987. "The Quest for a Functional LIS: A Case Study of Prince Williams County." Proceedings of IGIS Conference, Virginia, Nov. 15–18.

Sullivan, C. 1983. "Standards and Standardization. Basic Principles and Applications." Marcel Dekker, Inc.

Tamin, N. 1992. "A Methodology to Create a Digital Cadastral Overlay Through Upgrading Digitized Cadastral Data." Department of Geodetic Science and Surveying, The Ohio State University.

Tom, H. 1988. "Standards: A Cardinal Direction for GISs." Proceedings of the URISA Annual Conference, Vol. 2.

Wisconsin Land Records Committee. 1985. "Final Report of the Subcommittee on Geographic Reference Standards." December 1985.