FGCC

Multipurpose Land Information Systems
THE GUIDEBOOK

prepared by
The Federal Geodetic Control Committee

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MULTIPURPOSE LAND INFORMATION SYSTEMS:

THE GUIDEBOOK

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SECTION ONE

Section One contains background material on land information systems, mapping, and geodesy.

1 INTRODUCTION TO MULTIPURPOSE LAND INFORMATION SYSTEMS

Earl F. Epstein and Patricia M. Brown

A great deal of the work of local government—some say as much as 90 percent—relates to land, to its location, characteristics, value; to restrictions on its use, and claims on its resources. Local government agencies of all kinds have developed systems and procedures to help them do this work. For a long time, these have been manual systems, with records on paper, index card, and mylar. They included reports and maps, cross-indexing catalogs, log books, and chronological files. Formal and ad hoc numbering schemes and standard procedures were set up to maintain these systems. The records, numbering schemes, procedures, and people all make up the land information system.

The agencies that maintain these systems, as well as their users both in government and outside, recognize many shortcomings. Cross-referencing is inadequate; retrieval is inconvenient; the records are old, deteriorating, voluminous, outstripping storage space and getting in the way. On their own initiative or under pressure from users, many agencies with land information systems have introduced improvements ranging from new numbering schemes, mechanized storage and retrieval, microfilm, and microfiche to new maps, aerial photography and computer systems. But some of the most difficult problems for local governments to solve—problems that cause great inconvenience to users and cost to the taxpayers—are rooted in the separation of historical functions and their assignment to different divisions of government. Each governmental entity attends first to its specific mission. Coordination takes time, energy, and money, and many managers see it as detracting from their primary objectives. Coordination also takes conviction and a willingness to depend on someone else to do something necessary. As a result, most land information systems—old, new, improved, or otherwise—serve a single purpose and support the objectives of a single governmental entity.

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The central theme of this *Guidebook* is the *multipurpose* land information system. While the technical information may be useful to readers who will plan, design, implement or use LISs of all kinds, the vision for improving the Nation's land information emanates from a belief in the benefits of an information system designed to meet the many requirements of government and the private sector.

In 1980, the National Research Council published its report, *Need for a Multipurpose Cadastre*, which declared the "critical need for a better land-information system in the United States," and publicized the concept of the multipurpose cadastre—"a framework that supports continuous, readily available, and comprehensive land-related information at the parcel level" (NRC 1980, p. 1). The land records reform movement in North American already had a substantial history when this document was published.

The 1966 Comprehensive Unified Land Data (CULDATA) Conference culminated a 2-year effort by the U.S. Department of Agriculture and the American Bar Foundation "to develop a model system for a multipurpose land data system. In addition to a review of the model itself, the conference devoted considerable attention to the status of computer technology used to implement various functions of the CULDATA model, including mapping, surveying, and indexing" (Moyer 1980). Although dated, the proceedings from this conference document an important part of MPLIS history. (See *References and Additional Readings*.) The Mackinac Conference in 1969 focused on two issues related to land title records: legal requirements for the transfer of property rights, and the relationship between land title data and functions that use them. The American Bar Foundation sponsored the CLIPPP Conference (Compatible Land Identifiers—Problems, Prospects, and Payoffs) in 1973 to bring together representatives of the various disciplines that are involved in land records for workshop sessions (Moyer 1980). The development of a single, uniform method for identifying land parcels and related records was the major recommendation to come out of this conference. In 1974, a nonprofit organization of governmental agencies and professional organizations was incorporated as the North American Institute for Modernization of Land Data Systems (MOLDS) "to assist in the land records reform issue" (Moyer 1980). MOLDS sponsored two conferences and has published the results of research, including an annotated bibliography. This organization continues now as the Institute for Land Information (ILI). Conference activities in support of the land records movement continued through the 1970s and 1980s with the

Land Records Symposium in 1976, the Symposium on Land Registration and Data Banks in 1978, and an increasing level of activity among professional organizations.

These activities demonstrate the diversity of skills and professions interested in the various aspects of land information systems. The American Bar Association, the American Bar Foundation, the American Congress on Surveying and Mapping, the American Society of Photogrammetry and Remote Sensing, the International Association of Assessing Officers, the National Association of County Recorders and Clerks (an affiliate of the National Association of Counties), and the Urban and Regional Information Systems Association (URISA) have shown continuing and growing interest in land information systems.

Many prototype and demonstration projects, some successful, some not, have added to our understanding of how to implement land information systems (Moyer 1980). A review of the project histories, documented in reports and conference proceedings, shows the diversity of scope, intent, method, cost, and organization of multipurpose land information systems. And while each project, like each jurisdiction is unique, there are common problems and issues.

The 1980 *Need for a Multipurpose Cadastre* report has become a *de facto* standard for many looking for guidance, but while it identifies needs and requirements, and describes the roles of the various levels of government, it is not specific enough to guide implementation. To help meet this need, NRC published *Procedures and Standards for a Multipurpose Cadastre* in 1983. This report reiterates the most important findings and recommendations of the *Need for a Multipurpose Cadastre*, and goes on to make more specific recommendations regarding the many aspects of multipurpose cadastre implementation. Subjects range from the technical (geodetic reference frameworks and base mapping) to the organizational (institutional context, roles, and budget). This *Guidebook* is built on the foundation laid by these two publications. It shares with them a commitment to the vision of compatible, accurate land information available throughout the United States at all levels of government and supporting a wide range of uses.

For the people working in the hundreds and thousands of agencies that house this country's land information, this vision has not always been clear. Tremendous advances in computer technology are making many of the goals of a multipurpose land information system achievable. At the same time, the concept itself has been confused with the tools, techniques, and end products of its implementation. Down in the trenches, surrounded by daily pressures and problems, with limited access to other professionals, organizations and the literature, local government employees are trying get the picture through a haze of acronyms and vendor pitches: MPC, LIS, GIS, CAD/CAM, AM/FM . . ..

Although they are used interchangeably in some settings, each acronym was invented to convey a meaning slightly different from its predecessors. Many of the terms were invented to describe computer applications, software, and hardware, and they tend to be used in different fields of expertise and to carry slightly different connotations. AM/FM (Automated Mapping and Facilities Management), for example, is used among public works and utilities managers, while CAD/CAM (Computer Aided Design/Computer Aided Mapping) is more common among designers and mappers. (In the design world, CAD/CAM sometimes refers to Computer Aided Design/Computer Aided Manufacturing.) AM/FM implies functionality to support inventory management, work order processing and network analysis; CAD/CAM offers support for engineering design and mapping. The boundaries between various packages are becoming blurred as vendors extend their capabilities, but the origins of a package are reflected in its structure, and continue to affect its capabilities, strengths, and weaknesses. As important as hardware and software have become to the implementation of multipurpose land information systems, experienced users come to see them as only one part of the system of procedures, programs, people, and organization, as well as software, hardware, applications, and data. Nonetheless, the acronyms have generally retained an aura of automation, and for those just entering the field they often mean simply products.

The first person in a local government to become interested in multipurpose land information system or geographic information system is generally from a department that has as its focus land, its uses, and value, and that relies heavily on maps, such as public works, planning, property assessment, or title recording. The first step may be a visit to the Data Processing Department to discuss the possibility of computerizing some land information or a related function. Most Data Processing Departments have dealt almost exclusively with nonspatial information systems. Although many computer applications may have important spatial references, such as street address in 911 and building permit systems, the spatial reference is not a primary key to the system. Usually there is no way to relate data from different systems based on the spatial reference, nor any way to analyze the data based on location. These shortcomings reflect the origin and history of data processing in local government and can present a significant obstacle to automating a multipurpose land information system in this setting.

For the purposes of discussion, consider spatial information systems in three categories: GISs, LISs, and other spatial systems, such as CAD/CAM. The identification of various branches of spatial systems and the distinctions among them are less important than the range of information encompassed by the terms. In this *Guidebook*, we will be looking at ***land information systems***, which are the data, products, services, the operating procedures, equipment, software, people—the sum of all the elements that systematically make information about land available to users.

Historically, the term geographic information system (GIS) has referred to spatial information whose detail, accuracy, and precision generally corresponded to maps at scales of 1:20,000 or smaller. The products and analyses available from these systems are designed for policy decisions and planning. The information system was often built to support specific projects so that it was not necessarily tied to the day-to-day transactions of the institution.

Although there is no clear or widely accepted distinction between them, the term *land information system (LIS)* conveys a stronger orientation toward land records and a larger scale than the term *GIS* does. Much of the data and many of the sources are the same. In local government, an LIS could include the property appraiser's maps, maps on which approved subdivisions are compiled, utility maps, right-of-way maps, and zoning maps. It could also include all of the tabular records associated with the maps: the property assessment files, deeds, subdivision review applications and approved plans, inventories of pipes, manhole details, maintenance records, building permits, zoning applications, zoning violations and other code enforcement records. At the planning level, an LIS might incorporate road networks—existing, planned, funded—and related data on capacity and volume. It could include land use, land cover, projected or planned land uses, soils, environmentally sensitive areas, socio-economic data, redevelopment areas. For upper level management and elected officials, the LIS might provide information on projects, permit applications or taxes by election district, capital improvement programs and distributions of crime, school populations, complaints. In short, "a land information system is what a government or unit wants it to be and/or do and become what . . . [they] want it to become" (McLaughlin 1988 from Hodgkinson 1985).

In this *Guidebook*, we will use the term *multipurpose land information system* to refer to a system in which "the fundamental means of organizing data is the *cadastral parcel or proprietary land unit*," whose main objective is "the provision of institutional data concerning *land ownership, value, and use*" (McLaughlin 1988, p. 11, emphasis added). It is built to support a wide variety of applications. The underlying data should be *accurate* enough to support the envisioned applications, *compatible* so that data sets can be used in combination with one another, and *comprehensive* so that current and appropriate data are available when they are needed. A fully implemented multipurpose land information system should be incorporated into an environment that provides:

1. The fundamental land base
2. Data features on or near the Earth's surface
3. The means to interpret and manage these data—increasingly computer software
4. The media upon which data and management techniques reside, increasingly computer hardware
5. The means to represent and disseminate data and information
6. People organized to oversee the system operations
7. Procedures for using and maintaining the system.

Such a system would permit data to be used conveniently and accurately through spatial analyses, such as polygon overlay, area and distance calculations. It would also use interrelationships among data sets for tying maps to a common spatial reference system and for linking records through common identifiers.

In too many local governments, this list of land-related information and the associated governmental functions is matched by an equally long list of information systems, single purpose applications built to meet a single need, such as tracking building permits, monitoring subdivision applications, or appraising land for taxation. As a result, opportunities for cost savings, better service, better information, and better decisions are being lost every day at a substantial cost to society.

Growth and resource management decisions have high stakes. They are always uncertain and often the subject of controversy. Mistakes and poor decisions can be very costly and hard to correct. Current, accurate information about land should be readily available, at a reasonable cost, for the decision-making process. As a society, we seem to be willing to invest in better information. Continuing growth and increasing demand for shrinking resources will make current, accurate information even more valuable. Land is one of the most fundamental of resources. In the past, records of land resources have been poor, but as we recognize the value of these resources, and the limits to their availability and resilience, we will demand better information for our decisions.

The projected investment in automated LIS/GIS reflects our need to make that information available for record-keeping, public inquiries, analysis, and decision-making. Our existing land information systems do not meet these needs—a well-implemented multipurpose land information system can.

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NRC, *see National Research Council.*

National Academy of Sciences, *see National Research Council.*

National Research Council, 1980: *Need for a Multipurpose Cadastre*, National Academy Press, Washington, DC, 112 pp.

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SECTION TWO

Chapters in Section Two of the MPLIS Guidebook will continue to introduce technical material. These chapters also begin to explore in greater detail how the various functions of local and state government interact, and show how the information data base for the MPLIS can be linked and used to better serve these functions. Section Two thus provides the framework needed in Section Three, which deals with specifics of how one builds and maintains an MPLIS.

2 INTRODUCTION TO MAPPING CONCEPTS

Samuel T. Bardelson

Maps are abstractions of reality, an attempt to fit the world into a reduced or simplified view. They are primarily designed to answer two questions: where something is located relative to other things, and what is at a particular location. The job of the cartographer is to make a full-sized, three-dimensional world fit onto a two-dimensional map in such a way that these two questions are answered. Obviously, it would take an extra large map to portray all the features in the world accurately, and even then the job might be impossible. The cartographer must select and generalize features, representing them symbolically at a reduced scale, and identify them by name and type. This chapter introduces the mathematical and graphic design concepts that are important in understanding how to make and use maps.

PROJECTIONS

Map projections are a systematic representation of all or part of the surface of a sphere onto a plane. In other words, projections are a method of putting information from the Earth's surface onto the flat surface of a map. It is impossible to transfer Earth data to a plane surface without distorting either the measurable area or the shapes of Earth features. Many projections have been devised that minimize one or the other of these problems, but no single projection gives an absolutely true picture of the surface of the Earth.

There are two general categories of map projections: conformal projections and equal-area projections. On conformal maps, scale varies across the map in order to preserve the shape of any small area. The relative local angles about every point on the map are shown correctly and meridians intersect parallels at right angles. For this reason, nearly all large-scale maps produced by government agencies have conformal projections. An example of a conformal map is the Mercator map of the world. The magnification of the area of continents as they approach the poles is a vivid example of

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the area distortion that conformal maps can contain. Equal-area maps are such that a coin placed on one part of a map covers exactly the same area of the actual Earth as the same coin placed on any other part of the map. Shapes, angles, and scale must be distorted on most parts of an equal-area map. A map projection cannot be both conformal and equal-area, but many map projections are combinations that compromise between the two.

In the *Lambert conformal conic projection* (Figure 2-1) mapping is done on the surface of a cone which intersects the Earth along two latitude lines, or *standard parallels.* Along the intersecting lines, distances on the Earth correspond to distances on the cone. Beyond the parallels, the cone is outside the Earth and distances are longer than corresponding Earth distances. Inside the parallels, the cone is inside the Earth and distances are shorter than corresponding Earth distances. North-south lines have a changing scale; east-west lines have a constant scale. The *transverse Mercator projection* (Figure 2-1) uses a cylinder that intersects the Earth along two ellipses equidistant from a central meridian. Along the two ellipses, distances on the Earth correspond to distances on the cylinder. North-south lines have a constant scale; east-west lines have a changing scale.

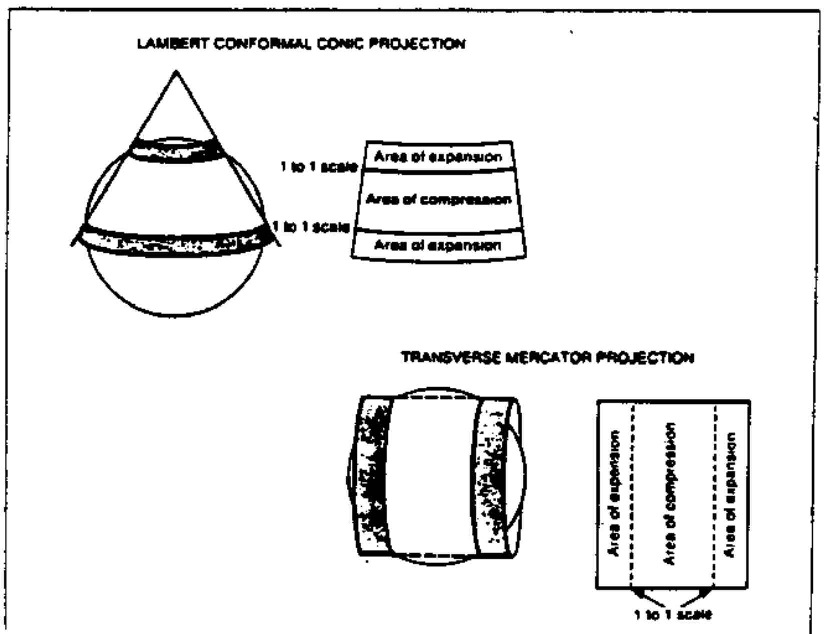

Figure 2-1: Construction of map projections.

COORDINATE SYSTEMS

Positions on the ground may be described in relative or in absolute terms. In Figure 2-2, we may know precisely where each stake is relative to the tree on the same side of the stream. But without a *tie* between the two trees or a coordinate system to which the trees or the stakes are tied, we do not know the absolute position of the stakes on the coordinate scheme, or their position relative to each other. In a land information system or map series, a land parcel is defined by the *parcel boundary*, generally four or more property corners and the lines connecting them. Each property corner has a position *relative* to the other corners of the parcel and to the corners of adjoining cadastral parcels. If a parcel corner is located with respect to a coordinate system, the position is also an *absolute* position. Of course, the absolute position is subject to the degree of accuracy of the survey that determined it. The idea of relative and absolute positions is important in a multipurpose land information system (multipurpose LIS or MPLIS) because one of the central objectives of the system is to tie all of the various features, including parcels, to a geodetic network so that both their absolute positions and their relative positions are known even though each feature is not tied to all other features.

Figure 2-2: Absolute and relative position.

LATITUDE AND LONGITUDE

The most common method of specifying location on the Earth's surface is by latitude and longitude. A *latitude line*, sometimes called a *parallel* (Figure 2-3), is a circle parallel to the equator. It describes location north or south of the equator. Values range from 0° at the equator to 90° at the poles. A *longitude line*, sometimes called a *meridian* (Figure 2-3), follows the shortest distance from pole to pole. It describes location east or west of the prime meridian. Values range from 0° at the prime meridian (which passes through Greenwich, England) to 180° east or west.

Figure 2-4 shows more precisely how latitude and longitude are defined. Imagine three planes cutting through the Earth like sheets of paper: the equatorial plane at the equator; the prime meridian plane; and the meridian plane of P, which cuts through point P and contains the meridian (longitude line) on which it lies. The intersection of two planes is a line. The intersection of the equatorial plane with P's meridian plane and the prime meridian plane defines two lines. The angle between those lines, measured from the prime meridian on the equatorial plane, is the longitude of P.

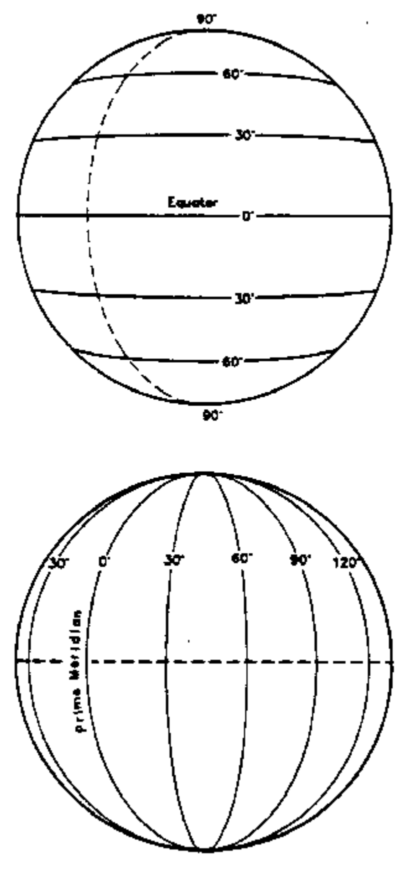

Figure 2-3: Parallels and meridians.

Latitude is more difficult to describe. Imagine a line drawn on P's meridian plane and perpendicular to the meridian at P. That line will intersect the equatorial plane close to the center of the Earth. P's latitude is the angle between that line and the equatorial plane, measured from the equatorial plane to the line in P's meridian plane.

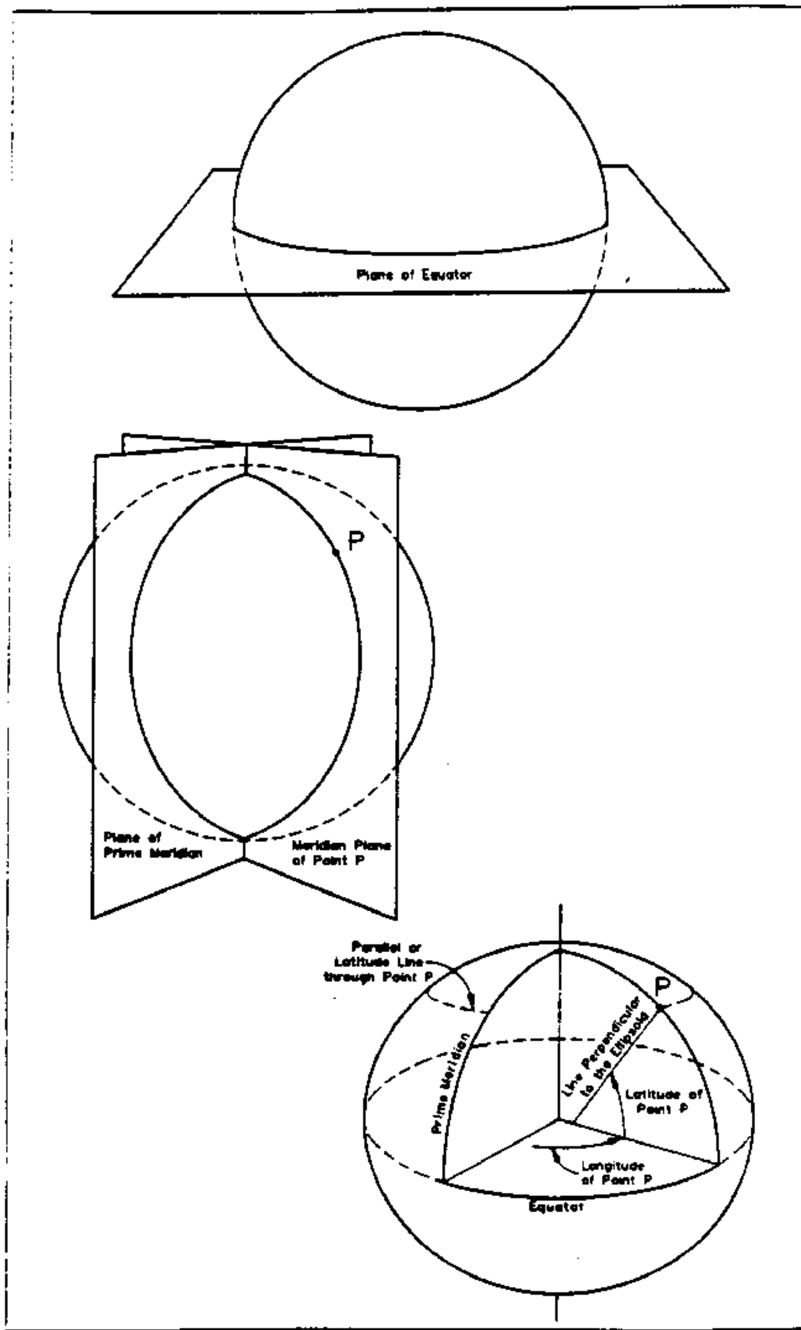

Figure 2-4: Definition of latitude and longitude.

Much work has been done over the years to develop an accurate mathematical description of the Earth's surface. The Earth's surface most closely resembles an oblate ellipsoid, bulging at the equator and flattened at the poles (Figure 2-5). As a result, the length of one degree of latitude increases very slightly as you approach the poles. The length of one degree of longitude decreases to zero as the meridians converge at the poles. Figure 2-5 illustrates these concepts where D equals the length of 30 degrees of latitude near the equator and E+ equals the length of 30 degrees of longitude at the equator.

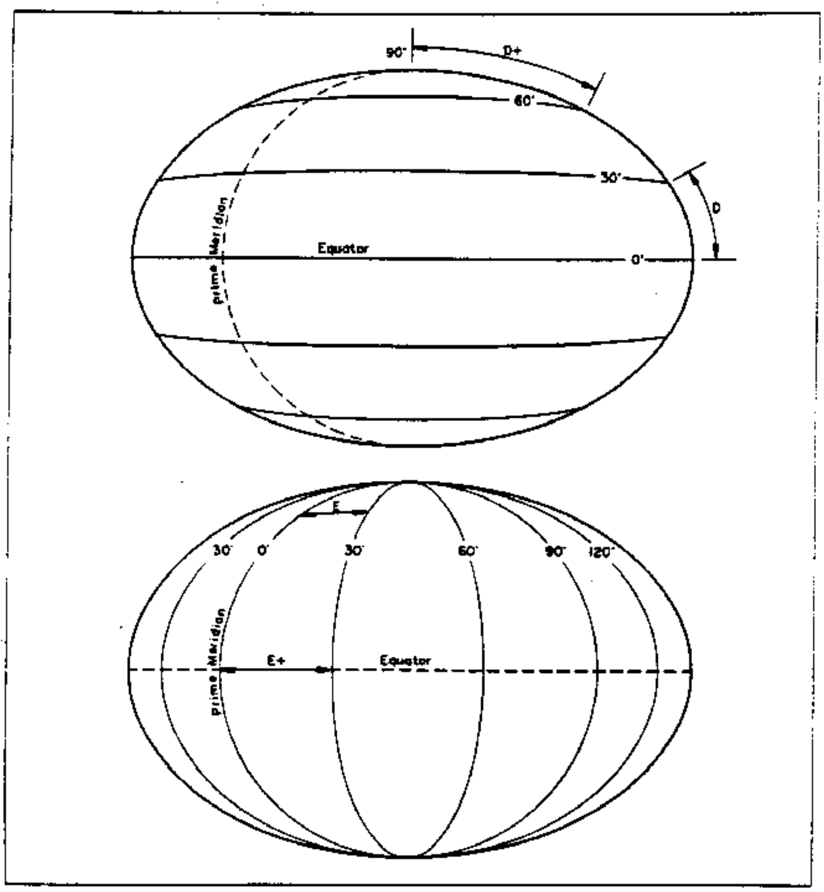

Figure 2-5: The Earth resembles an oblate ellipsoid.

PLANE COORDINATE SYSTEMS

Two plane coordinate systems are also commonly used to express position: the State Plane Coordinate System and the Universal Transverse Mercator grid system. *Universal Transverse Mercator (UTM)* coordinates (northings and eastings) are derived from a rectangular grid based on a transverse Mercator projection. The UTM system consists of 60 north-south zones, each 6° wide in longitude. The zones are numbered consecutively, starting with zone 1 between 180° and 174° W. longitude and increasing eastward to zone 60 between 174° and 180° E. longitude. The UTM system is designed to be used for latitudes between 80° S. and 84° N. and does not include the polar regions. Unlike state plane coordinates, UTM coordinates are available for the whole world (minus the poles). UTM coordinate values are given in meters.

The *State Plane Coordinate System (SPCS)* is a system of rectangular (X and Y) grid coordinates derived from one of two projections over a state or part of a state (zone). A Lambert conformal conic projection with two standard parallels is used for states having a large east-west extent. A transverse Mercator projection is used for states having a large north-south extent. Most states have more than one zone to minimize the distortions inherent in the projections, and the zone boundaries follow county lines. Computed state plane coordinates are available for horizontal geodetic stations established by Federal agencies. The State Plane Coordinate System is the system most commonly used by state and local governments and by private surveyors in the United States.

SCALE

Virtually all maps show features on the surface of the Earth at a much smaller size than the actual features. The scale of a map is the ratio of the length of a feature as measured on the map to the true length of the feature on the surface of the Earth, expressed as a representative fraction. For example, on a map at 1:2,400 scale, 1 inch on the map would represent 2,400 inches (200 feet) on the ground. Sometimes such a map is referred to as a 200 foot map or a 1"=200' map. Maps are said to be larger in scale as the denominator of the proportion gets smaller, and a larger scale map shows features larger than a smaller scale map. For example, 1:2,400-scale maps are larger scale than 1:10,000-scale maps. Larger scale maps would generally show more detail than a smaller scale map of the same area. On maps covering very large areas or the whole world, the scale varies over the map, and only a globe would be a true-scale replica. Table 2-1 lists some equivalencies and area covered for various scales.

Table 2-1: Scale equivalencies

Inch-Pound System

Scale	1 inch represents	At this scale, a 20" by 20" map covers:
1:1,200	100 feet	0.38 by 0.38 miles = 0.14 sq. miles *(2,000' by 2,000')*
1:2,400	200 feet	0.76 by 0.76 miles = 0.57 sq. miles *(4,000' by 4,000')*
1:4,800	400 feet	1.52 by 1.52 miles = 2.30 sq. miles *(8,000' by 8,000')*
1:12,000	1,000 feet	3.79 by 3.79 miles = 14.35 sq. miles *(20,000' by 20,000')*
1:24,000	2,000 feet	7.58 by 7.58 miles = 57.39 sq. miles *(40,000' by 40,000')*
1:63,360	5,280 feet	20 by 20 miles = 400 sq. miles *(105,600' by 105,600')*

Metric System

Scale	1 cm represents	At this scale, a 50 cm by 50 cm (19.7" by 19.7") map covers:
1:1,000	10 meters	0.5 by 0.5 km = 0.25 sq. km (0.1 sq. miles)
1:2,000	20 meters	1 by 1 km = 1 sq. km (0.4 sq. miles)
1:5,000	50 meters	2.5 by 2.5 km = 6.25 sq. km (2.4 sq. miles)
1:10,000	100 meters	5 by 5 km = 25 sq. km (9.7 sq. miles)
1:25,000	250 meters	12.5 by 12.5 km = 156.25 sq. km (60 sq. miles)
1:50,000	500 meters	25 by 25 km = 625 sq. km (241 sq. miles)
1:100,000	1,000 meters	50 by 50 km = 2,500 sq. km (965 sq. miles)

ACCURACY

Some maps, such as road maps, are designed to show only relative positions. Other maps have been designed and constructed to meet more stringent accuracy standards. A multipurpose land information system that includes a graphic depiction of the relationships between property parcels depends on a set of highly accurate large-scale maps.

Several systems of determining and expressing map accuracy have been devised, the most well-known of which is the National Map Accuracy Standards (Appendix 2-1). These standards cover both vertical and horizontal accuracy. Map accuracy is determined by checking the mapped position of a location, either horizontal or vertical, against its true ground position. National Map Accuracy Standards describe a method for determining the accuracy of map products: "on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch." For a map at 1:2,400 (1"=200'), that means no more than 10 percent of the points tested would be more than 6.67 feet from the position determined by a field check. For vertical accuracy, "not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval." No governmental or legislative requirement exists that a map meet National Map Accuracy Standards, except as required by the agency producing or contracting for the map.

The American Society for Photogrammetry and Remote Sensing (ASPRS) has recently developed another standard for classifying map accuracy for large-scale maps. The *ASPRS Interim Accuracy Standards for Large-Scale Maps* indicate accuracy at ground-scale and allow digital cartographic data of known ground-scale accuracy to be related to the appropriate map scale for graphic presentation at a recognized standard. Horizontal map accuracy is defined as the ***root mean square (RMS) error*** in terms of the project's planimetric survey coordinates (X, Y) for checked points as determined at full (ground) scale of the map. Based on the accuracy level achieved, maps are designated as Class 1, 2, or 3. These standards, and the limiting RMS errors (maximum permissible RMS errors) for Class 1 maps are included in Appendix 2-2 along with typical map scales associated with the limiting errors. These levels of accuracy apply to tests made on well-defined points only. For vertical accuracy on Class 1 maps, the limiting RMS error for well-defined points is set at one-third of the contour interval, and for spot elevations, one-sixth of the contour interval.

Map accuracy must be defined in the initial planning. For a typical photogrammetric mapping project, the required accuracy will affect the flying height of the aerial photography, the density of ground control and the stereocompilation instruments used. Once these parameters have been defined and the project started, greater accuracy would be difficult to achieve.

Table 2-2: Map accuracy standards

Horizontal accuracy examples

Scale	NMAS[1]
1:1,200	± 3.33 feet
1:2,400	± 6.67 feet
1:4,800	± 13.33 feet
1:9,600	± 26.67 feet
1:10,000	± 27.78 feet
1:12,000	± 33.33 feet
1:24,000	± 40.00 feet
1:63,360	± 105.60 feet
1:100,000	± 166.67 feet

[1] National Map Accuracy Standards define the requirements for meeting horizontal accuracy as 90 percent of all measurable points must be within 1/30th of an inch for maps at a scale of 1:20,000 or larger, and 1/50th of an inch for maps at scales smaller than 1:20,000.

Maps should be tested to determine whether or not they meet desired accuracy standards. Generally, the horizontal accuracy of a map is tested by comparing the planimetric (X,Y) coordinates of well-defined ground points on the map to the coordinates of the same points as determined by an accurate field survey. Well-defined points would include such features as road intersections, road-railroad crossings, or building corners. For testing vertical accuracy, spot elevations and elevations determined by contour interpolation are compared with elevations determined by an accurate field survey.

> Map accuracy determination is by no means an exact science. Map accuracy specifications and testing procedures cannot be so clear and mathematically incontrovertible that they will give the exact and only answer to the problem of evaluating the accuracy of a given map. There is an area of interpretation whose existence must be recognized to avoid rigidly applying narrow rules in a way that does not reflect the spirit or intent of the specifications.
>
> In a sense, accuracy specifications are akin to laws in a civil community. A law can be clearly written and apparently unmistakable in meaning, yet a case involving the application of that law may go through court after court with many variations in its interpretation. In the same way, a map may pass or fail, according to how the accuracy specifications are applied or interpreted.
>
> *(Thompson 1987, p. 105)*

Ideally, an agency contracting for large-scale mapping would have the coordinates for a number of check points that are not available to the contractor and a means for checking them against the compiled or digitized mapping. Usually an instrument such as a coordinatograph connected to a digital readout device is used for accuracy checking. Software is relatively simple and must perform a linear transformation between the actual coordinates of the check points and the sheet coordinates of the points as portrayed on a stable-base copy of the map. At the time of accuracy checking, the neatline of the quadrangle, or the values of the quadrangle corners can also be checked.

HORIZONTAL AND VERTICAL GEODETIC DATUMS

Latitudes, longitudes and heights are based on assumptions about the size and shape of the Earth. These assumptions are expressed in the *geodetic datum*, or *datum* which is defined as "a set of constants specifying the coordinate system used for . . . calculating the coordinates of points on the Earth" (NGS 1986). There are two kinds of datums: horizontal and vertical.

The *horizontal geodetic datum* used in the United States is being redefined. Currently, most of the existing maps in this country use the *North American Datum of 1927 (NAD 27)*. However, the National Geodetic Survey (NGS) has recently changed the datum of the country on the basis of additional horizontal observations and a new definition of the ellipsoid, GRS80. This new definition is called the *North American Datum of 1983 (NAD 83)*. The most commonly used *vertical geodetic datum* is the *National Geodetic Vertical Datum of 1929 (NGVD 29)*, but the National Geodetic Survey is developing a new vertical datum as well, the *North American Vertical Datum of 1988 (NAVD 88)*. The elevation values of most vertical control marks in the country will be adjusted with NAVD 88. The reference datums are discussed more thoroughly in Chapter 3, "Introduction to Geodetic Reference Frameworks," in this *Guidebook*.

The cartographer or the person contracting for mapping must be aware of which datum is being used. *Positions from one datum cannot be used on the same map with positions determined on another datum, without converting one data set*. For horizontal positions, this problem will be apparent immediately, but for vertical control the problem will become apparent in the 1990s with the redefinition of the vertical datum. *Global Positioning Satellite* technology gives positions based on NAD 83, and the increasing use of this technology will intensify the problem.

THE BASE MAP

A base map for a multipurpose land information system can take one of many forms. Several factors influence the form of the base map, including cost, intended use, and the type of existing maps. The most common forms of base maps are *line maps, photomaps* and *orthophotomaps*, and *digital maps*.

Line maps are typically scribed or inked and can be multi-color or black and white. A line map usually includes roads, buildings, fences, vegetation, control and other monumented points, railroads, trails, transmission lines, and pipelines. A topographic line map also contains information representing the ground surface, typically through the use of contours. A planimetric line map would not contain relief information.

Photomaps and orthophotomaps are other frequently used forms of base map. The advantages of a photographic base include lower cost and abundant detail. All of the information on the ground is included on the photograph, although some ground information can be partially obscured or too small to be visible. Important features such as jurisdictional boundaries or land parcels are generally not visible. Conversely, a photographic base map may have such an abundance of detail that relevant information may be difficult to interpret. Skilled photo-interpreters may be needed to use the photographic base map to its full potential.

A photographic base map can be either an enlarged photograph, a rectified photograph, or an orthophotograph. Aerial photographs are subject to several types of distortion, as shown in Figure 2-6. A photograph can be enlarged to a nominal scale, but displacements from tilt and relief prevent the photograph from having a uniform scale. An unrectified enlargement of an aerial photograph would not meet National Map Accuracy Standards, and would be a very poor base for a multipurpose land information system. A rectified photograph is one that has been corrected for tilt, but not for relief displacement. In extremely flat areas, such as California's Central Valley, a rectified photograph may meet National Map Accuracy Standards, depending upon the scale and other factors. An orthophotograph is a photograph whose image has been photogrammetrically manipulated so that features on the photograph are in true *orthographic* position. A properly made orthophotograph with sufficient horizontal and vertical control will meet accuracy standards appropriate to the scale.

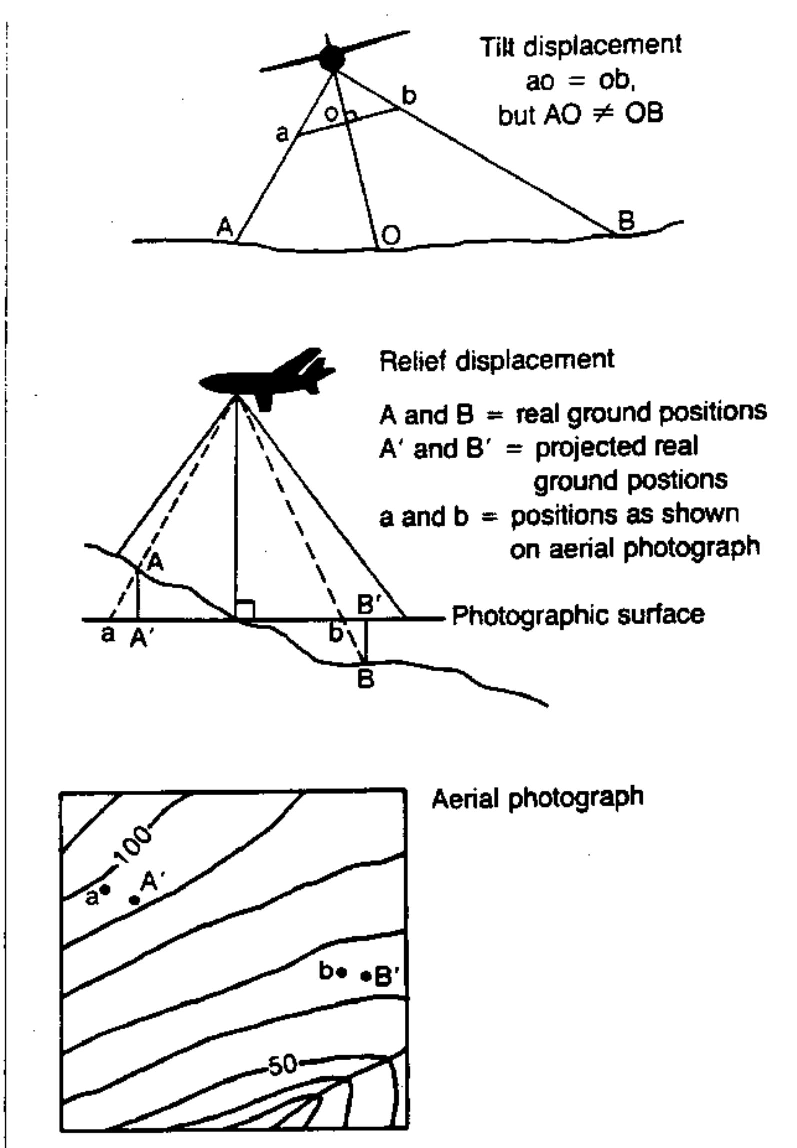

Figure 2-6: Causes of displacements on aerial photographs.

A map in digital form is more flexible than other forms of maps. Selective features can be viewed and displayed as desired, and data from different sources and scales can be merged. However, with this flexibility come additional problems. Mixing data at different scales can degrade the accuracy of the map. For example, data that meet the accuracy standards for 1:4,800-scale cannot be merged with data at 1:2,400-scale and be assured to meet 1:2,400-scale standards.

Ultimately, the mixture of data from several sources at different scales and accuracies can lead to a cartographic nightmare. Another problem with a digital map is the production expense. Digital maps can be produced by digitizing existing maps, by digitizing aerial imagery during stereocompilation, or by direct entry of coordinate data into the database. Substantial costs are involved in either acquiring digital mapping hardware and software and developing an in-house capability or in contracting for digitizing services. Additionally, the cost of database maintenance is often overlooked. Digital mapping systems are designed to be easily revised. If the data are not kept current, one of the main advantages to a digital system is negated. Still, the many advantages of a digital map seem to outweigh the disadvantages, and current state-of-the-art mapping systems are all digital.

The selection of the form of the base map for a multipurpose land information system depends upon the intended use of the maps, the funds available for developing the system, and other factors such as the extent and content of current maps. One form of map is not inherently superior to the others, and it is possible to move from one form to another. For example, a city or county developing a multipurpose land information system might use a set of orthophotographs at 1:2,400-scale initially. Cadastral parcels could then be delineated on the orthophotographs and unique identifying numbers generated for or associated with each parcel. The parcels and selected information from the orthophotographs could be digitized at a later time. MPLIS developers should keep in mind, however, that it is easy to build a less accurate map on a more accurate base, but virtually impossible to build a more accurate map on a less accurate base.

MAP DESIGN CONSIDERATIONS

Map design considerations determine whether a map is legible and easily interpreted. *Scale* is one of the first decisions made in map design. The selection of scale is based on the sources of information and the intended use of the map, as well as the *accuracy* and *content* requirements of the map. Other factors, such as sheet size, past practice, and the scale of auxiliary maps may also influence the selection of scale.

Maps are *selective in content*, consistently representing the features that are important for the intended use of the map and omitting others. Through selection and the choice and placement of symbols and annotations, maps also emphasize some features and de-emphasize others. In contrast, aerial photographs are not deliberately selective and may lend emphasis to large or distinctive yet irrelevant features while more relevant features may be missing or obscured.

Maps represent features using *symbols*, which should be standard at least for that map or map series. Many conventional uses of symbols, lettering, and color have evolved. Generally, adherence to these conventions will make a map easier to read. A map legend should define any unusual symbols used, but the more self-evident the symbology is, the better. In addition to pictorial symbols, line type and line weight are symbols, as are color and fill pattern. The style, size, and weight of *lettering* and its placement on the map can enhance or detract from a map's readability. The use of too many styles, too much variety in weights (boldness) or sizes, or careless use of capitalization will confuse the map reader and clutter the map. Convention guides the placement of names, their spacing, rotation, and direction, and whether they are on a straight line or curved along a feature. Map series that are maintained constantly by local government personnel are the products of many years and many hands. It is not uncommon to see a great deal of variation in symbology, lettering, and other cartographic decisions, particularly in the absence of written standards. Development of a multipurpose LIS provides an ideal time to develop, review, or implement such standards.

Most maps have a *title block* or *legend* showing the title of the map, its scale, projection, datum, information on its date of production and accuracy, and the source or producer of the map. If the map is one of a series, there will often be a grid reference, such as a U.S. Geological Survey quadrangle name, or section, township, range, and perhaps a context map or other indication of neighboring map sheets. Many maps also include coordinate system references or tick marks.

Every map is a *generalization* of features to some degree, representing a whole city by its boundaries or even by a symbol. The intricacies of coastlines and the twists and turns of rivers and roads are simplified for the sake of legibility and appearance. The difference in the degree of generalization can be an important limitation in creating map products at various scales by enlarging or reducing the same original.

The information required for a single map sheet may be represented on several sheets or *separates*. A *registration system*, is essential to ensure that the separates overlay properly during reproduction. Separates are required for multicolor maps, but they also enable the map maker to create essentially new maps through recombination, reduction, or enlargement. A carefully planned and produced set of map separates can support several map series and greatly reduce the amount of time required to keep maps up-to-date. Scale, content, symbolization, lettering, generalization, and layout must be considered carefully to guarantee flexibility and legibility of the maps.

In its guidelines for large-scale mapping (USGS 1986), the U.S. Geological Survey suggests six separates for large-scale community maps for display at scales between 1:1,200 and 1:4,800.

1. Streets, drainage, boundaries, rights-of-way, and names data.
2. Hypsographic information in the form of contour lines and vegetative information.
3. Buildings.
4. Surface and underground service and utility lines.
5. Property lines and lot and block data.
6. Property data and street addresses.

These separates could be used individually or combined in a number of different ways. For example, separate 1 could be the base for the official community map; separates 1, 2, and 3 could be the base for conventional topographic maps; and separates 1, 5, and 6 could serve as an assessment map.

The idea of separating different kinds of information is also important in digital mapping. The computer is not limited by the physical constraints imposed by reproduction, therefore, the number of separates, or *layers*, in a computer mapping system can be much larger. While the concept of explicitly distinguishing features is common in most computer systems that support mapping, the implementation methods and terminology vary.

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APPENDIX 2-1
UNITED STATES NATIONAL MAP ACCURACY STANDARDS

With a view to the utmost economy and expedition in producing maps which fulfill not only the broad needs for standard or principal maps, but also the reasonable particular needs of individual agencies, standards of accuracy for published maps are defined as follows:

1. Horizontal Accuracy. For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is well defined will also be determined by what is plottable on the scale of the map within 1/100 inch. Thus while the intersection of two road or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class would come timber lines, soil boundaries, etc.

2. Vertical accuracy, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

3. The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy. Tests shall be made by the producing agency, which shall also determine which of its maps are to be tested, and the extent of such testing.

4. Published maps meeting these accuracy requirements shall note this fact on their legends, as follows: "This map complies with National Map Accuracy Standards."

5. Published maps whose errors exceed those aforestated shall omit from their legends all mention of standard accuracy.

6. When a published map is a considerable enlargement of a map drawing (manuscript) or of a published map, that fact shall be stated in the legend. For example, "This map is an enlargement of a 1:20,000-scale map drawing," or "This map is an enlargement of a 1:24,000-scale published map."

7. To facilitate ready interchange and use of basic information for map construction among all Federal mapmaking agencies, manuscript maps and published maps, wherever economically feasible and consistent with the uses to which the map is to be put, shall conform to latitude and longitude boundaries, being 15 minutes of latitude and longitude, or 7.5 minutes, or 3-3/4 minutes in size.

U.S. BUREAU OF THE BUDGET

Issued June 10, 1941
Revised April 26, 1943
Revised June 17, 1947

APPENDIX 2-2
ASPRS Interim Accuracy Standards for Large-Scale Maps

Horizontal map accuracy is defined as the rms error in terms of the project's planimetric survey coordinates (X, Y) for checked points as determined at full (ground) scale of the map. The rms error is the cumulative result of all errors including those introduced by the processes of ground control surveys, map compilation, and final extraction of ground dimensions from the map. The limiting rms errors are the maximum permissible rms errors established by this standard. The limiting rms errors for Class 1 maps are listed below. These limits of accuracy apply to tests made on well-defined points only.

Planimetric (X or Y) Accuracy (limiting rms error, *feet*)	Typical Map Scale
0.05	1:60
0.1	1:120
0.2	1:240
- - - - - - - - - - - - - - - - [1]	
0.3	1:360
0.4	1:480
0.5	1:600
1.0	1:1,200
2.0	1:2,400
4.0	1:4,800
5.0	1:6,000
8.0	1:9,600
10.0	1:12,000
16.7	1:20,000

Planimetric (X or Y) Accuracy (limiting rms error, *meters*)	Typical Map Scale
0.0125	1:50
0.025	1:100
0.050	1:200
- - - - - - - - - - - - - - - - [1]	
0.125	1:500
0.25	1:1,000
0.50	1:2,000
1.00	1:4,000
1.25	1:5,000
2.50	1:10,000
5.00	1:20,000

[1] Indicates the practical limit for aerial methods; for scales above this line, ground methods are normally used.

Vertical map accuracy is defined as the rms error in elevation in terms of the project's elevation datum for well-defined points only. For Class 1 maps the limiting rms error in elevation is set by the standard at *one-third* the indicated contour interval for well-defined points only. Spot heights shall be shown on the map within a limiting rms error of *one-sixth* of the contour interval.

Lower Accuracy Maps

Map accuracies can also be defined at lower spatial accuracy standards. Maps compiled with limiting rms errors of twice or three times those allowed for a Class 1 map shall be designated Class 2 or Class 3 maps respectively. A map may be compiled that complies with one class of accuracy in elevation and another in planimetry.

Root Mean Square Error

The root mean square (rms) error is defined to be the square root of the average of the squared discrepancies. In this case, the discrepancies are the differences in coordinate or elevation values as derived from the map and as determined by an independent survey of higher accuracy (check survey). For example, the rms error in the X coordinate direction can be computed as:

$$rms_x = \sqrt{(D^2/n)}$$

where: $D^2 = d_1^2 + d_2^2 + \ldots + d_n^2$

$d =$ discrepancy in the X coordinate direction
$d = X_{map} - X_{check}$

$n =$ total number of points checked on the map in the X coordinate direction

3 INTRODUCTION TO GEODETIC REFERENCE FRAMEWORKS

James E. Stem and Gary M. Young

The need for accurate national surveys was recognized, in concept, by the founding fathers of the United States. Land transportation in the colonies was difficult, and commerce between the states was mainly by coastal shipping. Similarly, foreign trade, which was critical to the new Republic, was entirely by sea. The commercial shipping lanes were, for the most part, uncharted or inadequately charted, and shipwrecks were common. The responsibility of the central government was spelled out in the so-called commerce clause of the Constitution which provided that Congress shall have the power "to regulate commerce with foreign nations, and among the several states, and with the Indian Tribes." As part of this obligation, Congress, acting on a recommendation by President Thomas Jefferson, adopted a resolution on February 10, 1807, for a "Survey of the Coast." This act authorized President Jefferson "to cause a survey to be taken of the coasts of the United States, in which shall be designated the islands and shoals, with the roads or places of anchorage, within twenty leagues of any part of the shores of the United States; and also the respective courses and distances between the principal capes or head lands, together with such other matters as he deem proper for completing an accurate chart of every part of the coasts within the extent aforesaid."

By this act was created the first United States civilian scientific agency, the Survey of the Coast. Later the responsibility for surveys of the interior was added to its original mission to chart coastal waterways to assist waterborne commerce. The authorizing legislation for this new task was passed on March 3, 1871, calling for "a geodetic connection between the Atlantic and Pacific coasts" (Shalowitz 1964). It was this added responsibility to provide geodetic control for the interior of the country that led to the Act of June 20, 1878, which changed the name of the agency to *Coast and Geodetic Survey*. In 1970 the Coast and Geodetic Survey

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became a component of the National Oceanic and Atmospheric Administration (NOAA) and is presently named the National Ocean Service (NOS). To acknowledge the geodetic aspect of its mission, the portion of NOS responsible for geodetic activities was named the *National Geodetic Survey (NGS)*.

Today NGS is responsible for establishing, developing, and maintaining the *National Geodetic Reference System (NGRS)*. The NGRS comprises more than 800,000 accurately located survey points called *geodetic stations* and serves as the common surveying and mapping base of reference for latitude, longitude, height, scale, and orientation throughout the United States.

The Federal Geodetic Control Committee (FGCC) was organized to assist the Department of Commerce in meeting the requirements of the Office of Management and Budget (OMB) Circular A-16, dated May 6, 1967. FGCC consists of representatives from 11 departments and independent agencies that have geodetic and related survey activities and interests. Geodetic survey activities of these departments are coordinated by FGCC. FGCC also develops and publishes standards and specifications, and performs instrument testing for compliance to manufacturers specifications.

THE USES OF GEODETIC REFERENCE FRAMEWORKS

A *geodetic reference framework (GRF)* consists of permanently monumented stations whose locations are accurately measured and mathematically described relative to a common datum. (Chapter 2, "Introduction to Mapping Concepts," contains an introduction to the concept of datums.) In engineering, a geodetic reference framework provides the structure to support surveys, mapping, and construction. For a multipurpose LIS, the framework provides an accurate and efficient means to describe the location of land features and their relationship to one another, and makes it possible to interpret, analyze, and disseminate compatible land information. By *compatible* we mean related, or *tied*, to the same geodetic reference framework. The exact spatial relationship among the points in the framework is known, so the relationship between features that are related to these points is known. An adequate geodetic reference framework ensures sufficient spatial accuracy for linking the different types of data that comprise a multipurpose LIS.

Surveyors, mappers, and engineers routinely rely on a reference framework of some type to provide spatial control. For small projects, isolated field surveys may be performed to establish a temporary reference framework for that project. Larger projects often use the NGRS or a *local geodetic reference framework* consisting of the NGRS stations, plus other stations tied to the NGRS by less accurate surveys for spatial control.

THE LOCAL GEODETIC REFERENCE FRAMEWORK

Surveying activities performed by state, local, and private agencies often originate at the NGRS geodetic stations. When Federal standards and specifications are used to perform and connect surveys of other agencies to the NGRS, the surveys all become part of a single spatial reference system. *A local geodetic reference framework consists of the NGRS geodetic stations plus all properly connected stations of other agencies, whether they are included in the NGRS database or not.* NGS encourages private and public sector users to use and improve both the NGRS and local geodetic reference frameworks for the development of multipurpose LIS and for traditional engineering, surveying, and mapping.

FGCC specifications for traditional survey methods call for at least two ties to known positions to provide horizontal spatial control for a project. Specifications for vertical control call for four or more ties to known positions. Requirements for satellite methods differ. The positions can be expressed in the NGRS or geodetic reference framework coordinate system or their derivatives, or in an arbitrary coordinate system established for the project. The latter method of establishing single-purpose control in the form of a project-specific control system is often uneconomical in the long run, as it will not be consistent with other project-specific control systems in the future. Either way, the principle of spatial control is the same, that is, the geodetic survey points provide position, scale, and orientation for the project. When the spatial relationship between two projects is needed, however, a project-specific reference framework is not enough. The position, scale and orientation of each project to the other can be established by tying the two project reference frameworks together. Distance or field conditions may make this tie difficult, but even when it has been made, no relationship has been established between these two projects and any other projects or features. Tying projects to a geodetic reference framework that is, in turn, tied to the NGRS ensures that the relationship between projects is known, regardless of distance or field conditions.

Given at least two *horizontal geodetic stations* in a project, the computed distance between these points provides the scale of the project and the computed azimuth or bearing between these points provides orientation for the project. A common geodetic reference framework also creates a link between disparate types of data. For example, USGS 7-½ minute quadrangles refer to the NGRS and the 1927 datum (NAD 27). Any other map referring to the same datum, to the NGRS, or to a geodetic reference framework property tied to the NGRS, would be *compatible* with the USGS 7-½ minute series.

CHARACTERISTICS OF A GEODETIC REFERENCE FRAMEWORK

A geodetic reference framework has five characteristics:

- monumentation and field descriptions
- field measurements and methods
- survey accuracy
- density
- datum

MONUMENTATION AND FIELD DESCRIPTIONS

The physical evidence of a geodetic reference framework on, or near, the Earth's surface is provided by *geodetic stations*. Such stations are typically well defined points in manmade monuments, landmarks, or natural features. Most stations are metal survey disks set in concrete posts or bedrock outcrops. Some points are marked by steel rods. They usually extend far underground for stability and may have a metal survey disk or logo cap attached to the top. Usually stamped into the disk or logo cap are station-identification and establishing-agency information, plus an indicator of the precise point of the station for which a geodetic position is available. Monuments for survey stations other than *geodetic stations* also exist in the field, but until information for the station is obtained from the establishing agency, the station's utility or function is often unknown.

Geodetic stations must be very stable in order to provide an effective, multipurpose framework over time. All station monuments are subject to the effects of local soil activity, but by careful site selection and monument construction, such movement can be minimized. Vertical bench marks are particularly vulnerable to movement because displacement results in relatively larger vertical motion than horizontal motion. Consequently, monumentation for vertical stations differs from that used for horizontal stations. Monumentation designed for combined horizontal and vertical stations (i.e., *three-dimensional, or 3D, stations*) must be stable both horizontally and vertically. In addition to natural disturbances, construction and vandalism can damage, displace, or entirely remove stations. These create problems in maintaining monumentation.

Monument stability refers to the ability of a monument to maintain a fixed physical position over time. It is characterized by the degree and duration of stability. To a local surveyor running a topographic survey on a small construction site, a stable point can be the top of a prominent boulder or a spike driven into a gravel road surface. These objects could move 1 to 10 centimeters or more in a year's time, but still be adequate for this surveyor's needs. Another surveyor might be concerned with laying out a major highway that could take years to complete. The monumentation for this project must be more stable and longer lasting. In this case, a concrete post extending to a depth of 1 meter or so, or a spike in the side of a large utility pole, might be considered stable points. Required stability depends on the accuracy of the survey and the duration of the project for which accurate positions are needed.

In order to maintain the NGRS for all its intended purposes, NGS establishes monuments of very high stability, to minimize their movement due to local ground effects. Floyd (1978) and *Coast and Geodetic Survey Technical Manual 4* (1968) describe the establishment of the primary station for which the position or height is determined. Other, less stable peripheral monuments called *reference marks*, are often established near primary horizontal stations to aid in locating or relocating the primary station. Another peripheral monument, an *azimuth mark*, provides a point to which an accurate azimuth or bearing can be determined.

A vital part of geodetic information is the *field description* of the primary and peripheral station monuments, together with "to reach" instructions that describe the drive (sometimes the hike) to the stations, starting from a well-known landmark, such as a road intersection (FGCC 1989).

FIELD MEASUREMENTS AND METHODS

Geodetic surveyors use both terrestrial and satellite survey methods to locate positions of geodetic stations. Positions of horizontal geodetic stations are expressed in geodetic coordinates of latitude and longitude. (These are also called *horizontal control stations*, *triangulation stations*, or *traverse stations.)* Latitude and longitude are often mathematically converted, or *projected*, to the State Plane Coordinate System (SPCS) of X, Y coordinates (or northings and eastings), or some other map projection system. For *vertical geodetic sta-*

tions, also called *vertical control stations*, a very accurate height or elevation of the station has been determined. Of the various height systems, *orthometric height* is most commonly used. For the NGRS stations, orthometric height is defined as the distance between the vertical reference surface and the vertical geodetic station on the surface of the Earth, measured along the plumb line between the two. Orthometric height is positive upward from the datum surface. (See Horizontal and Vertical Datums, below, for a discussion.) The NGRS stations for which highly accurate orthometric heights have been determined from geodetic leveling are commonly called *bench marks*. In this *Guidebook*, the terms *bench mark* and *vertical geodetic station* are used interchangeably.

When *terrestrial survey methods* are used, a survey usually establishes horizontal stations or vertical stations, but not both. Consequently, only occasionally is a horizontal geodetic position determined for a bench mark, or a geodetic-quality height determined for a horizontal station. With *satellite surveying methods*, it is common to establish a *three-dimensional (3D) position* of latitude, longitude, and height, although satellite-derived orthometric heights are usually less accurate than those determined by terrestrial vertical control surveys. When discussing characteristics of the NGRS or geodetic reference frameworks, horizontal and vertical stations are addressed separately, while the properties of 3D stations attempt to satisfy both horizontal and vertical requirements. So while a horizontal station monument is constructed to resist horizontal movement and a vertical station monument is constructed to resist vertical movement, a 3D monument must resist both horizontal and vertical movement.

The quantities measured in a field survey—the *observations*—are used to compute geodetic latitudes, longitudes, and heights. In a terrestrial horizontal survey, the primary observables are angles, distances, and azimuths (bearings). In a terrestrial vertical survey, the primary observables are height differences. In a 3D satellite survey, the observables are radio signals transmitted by satellites.

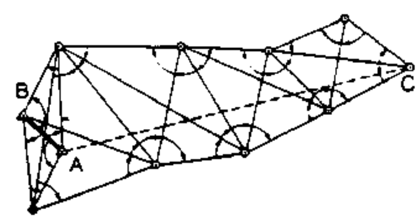
Terrestrial Methods

Coordinates for horizontal stations determined by terrestrial methods are established using one or a combination of three basic surveying methods: *triangulation*, *trilateration*, and *traverse*. A *triangulation* system consists of a series of connected or overlapping triangles in which the lengths of some of the sides are measured and the remaining side lengths are calculated from angles measured at the vertices of the triangles. *Trilateration* is similar in that a network is also formed by a series of triangles, but differs in that all the sides of the triangles are measured and only the angles required to establish orientation are observed. Figure 3-1 illustrates chaining of triangles to form an *arc of triangulation.* This was the primary means of extending horizontal control and establishing new geodetic horizontal stations within the NGRS until the early 1980s. Most of the horizontal portion of the NGRS was surveyed using this technique. In urban areas, triangles were chained together to form area networks. With the advent of precise electronic distance measurement instruments in the 1960s, the accuracy of the NGRS was gradually increased as an increased number of measured distances, which can be measured more accurately than angles, were incorporated gradually. At the same time, the practical differences between triangulation and trilateration have become less distinct.

Coördinates can be calculated sequentially from a *traverse,* which is a series of measured angles and distances. Figure 3-2 depicts a simple traverse between points A and C, which have previously established positions. The measured angle at station A between stations B and 1 is added to the known azimuth of line AB to give the azimuth of line A1. The distance between A and 1 is measured, processed, and combined with the azimuth to calculate the coordinates of station 1. This process is repeated until the position of station C is computed. The computed position of C is compared to the previously established position of station C, and the discrepancy is prorated over all traverse stations by an appropriate data distribution technique such as a least squares adjustment.

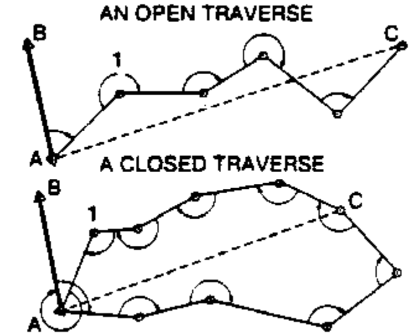
Geodetic leveling techniques are the terrestrial methods of establishing vertical stations. The fundamental observation in leveling is the height difference between two nearby points on the ground. Figure 3-3 illustrates how a leveling instrument is set up midway between two points so its horizontal line of sight intersects graduations on the two leveling rods set vertically on the points (Fig. 3-3). From the readings on the leveling rods, observed height differences are determined. When leveling between two widely separated points, it is necessary to set the leveling rods on intermediate temporary points, called *turning points,* and accumulate a series of height differences until the overall height difference between permanently monumented bench marks is determined. If proper equipment, observing procedures, and data reduction techniques are followed, the accuracy of these height differences can be sufficient to establish heights of geodetic quality.

A SIMPLE TRIANGULATION NET



KNOWN DATA:
Length of base line AB.
Latitude and longitude of points A and B.
Azimuth of line AB.
MEASURED DATA:
Angles to new control points.
COMPUTED DATA:
Latitude and longitude of point C, and other new points.
Length and azimuth of AC.
Length and azimuth of all other lines.

Figure 3-1: Triangulation (from DOD 1983, p. 15).



KNOWN DATA:
Latitude and longitude of points A.
Azimuth of line AB.
MEASURED DATA:
Length of traverse sides.
Angles between traverse sides.
COMPUTED DATA:
Latitude and longitude of point C, and other new points.
Length and azimuth of AC.
Length and azimuth of line between any other two points.

Figure 3-2: A traverse (from DOD 1983, p. 25).

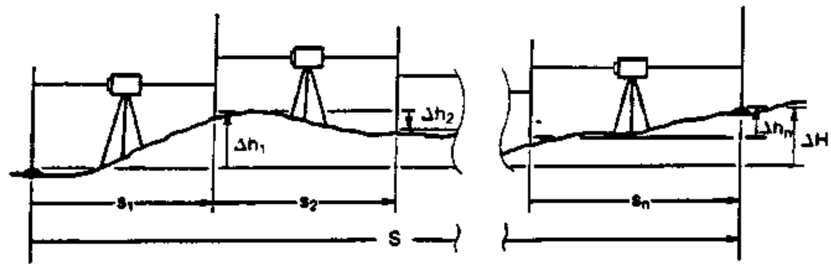


Figure 3-3: Geodetic leveling (from Schomaker 1981)

$\Delta H = \Delta h_1 + \Delta h_2 + \ldots + \Delta h_n$ *and* $S = s_1 + s_2 + \ldots + s_n$.

The observed height differences between bench marks are corrected for significant systematic errors and processed through least squares adjustments using heights of previous NGRS bench marks to determine new heights referred to the vertical datum. This process creates an interrelated network of benchmarks through which height values and differences can be compared for locations that are not directly tied by lines of geodetic leveling. Other methods are available, but geodetic leveling still provides the most accurate determinations of height differences for surveys of limited extent.

Satellite Methods

The *Global Positioning System (GPS)*, incorporating U.S. Department of Defense NAVSTAR satellites, is revolutionizing geodetic surveying. GPS is a very new technology compared to traditional horizontal and vertical geodetic surveys, which have a United States tradition dating back more than 175 years. Department of Defense development began in 1978 with the intention of designing a real-time navigation system, and practical geodetic receivers became available for civilian use in the early 1980s. NGS conducted its first GPS field tests in 1983. By the early 1990s, the GPS constellation of 21 satellites will be complete. This will provide 24-hour simultaneous visibility of at least four satellites almost anywhere on the Earth's surface. As GPS ground receivers become less expensive and more reliable, the advantages of GPS over traditional terrestrial surveying will become even more pronounced. GPS surveys are now used routinely to determine coordinates of new geodetic survey points. In many situations, GPS provides both economic and accuracy advantages over terrestrial surveying, although station height measurements may be less accurate.

GPS offers a number of practical advantages over terrestrial methods. GPS receivers can be operated in almost all types of weather, both day and night. Intervisibility of stations is no longer required. Longer distances between stations can be accommodated by the simultaneous occupation of more than one station, and less skill is usually required of the field observer. A disadvantage is that GPS receivers are sometimes unable to receive sufficient satellite signals when skyward obstructions exist, such as in urban and forested areas.

The position of a GPS receiver placed on ground control stations can be determined by processing specific radio signals transmitted by the GPS satellites. For geodetic applications, simultaneous observations are usually made at three or more stations, where the NGRS positions of at least two stations are known. This method of observation, called *relative positioning* or *differential mode,* provides a *base line vector* (direction and distance) between new geodetic stations and existing NGRS stations. Base lines accurate to 1 to 5 centimeters over distances of as much as 100 kilometers between stations can be routinely measured. Careful post-processing of sufficient GPS data provides geodetic-quality horizontal coordinates of the new stations relative to the previously determined coordinates of the NGRS stations. Using appropriate techniques and procedures, relative GPS-derived heights can be estimated with accuracies that are sufficient to meet many engineering needs (Zilkoski and Hothem 1989).

SURVEY ACCURACY

In any large surveying or mapping project, it is first necessary to establish a framework of geodetic stations to provide a common basis for operation and a coherent product. All positions are then determined *relative* to the framework. For the surveyor, the term *absolute position* is essentially unmeasurable. (The use of absolute and relative is different from common LIS/GIS usage.) *The reference framework must be more accurate than the most demanding project requirement,* so that within the project the small errors in the framework will not significantly affect subsequent, less accurate measurements. Conceptually, the geodetic reference framework "is the equivalent of the survey control system for a map," and the same principles apply to its design and implementation (NRC 1983, p. 23). *The NGRS provides the only national (and statewide) system of control that can provide spatial correlation of independent data sets.* It is for this reason that the National Research Council cites the NGRS as the foundation by which all land data must be related (NRC 1983).

Horizontal and Vertical Accuracy

It is neither economical nor practical for all points in the NGRS to be of the highest possible accuracy. FGCC, which is responsible for publishing national control classifications, has established a classification of accuracy, defining five orders of horizontal control and three orders of vertical control. Several orders are further broken down according to classes. FGCC publishes specifications for each of the classifications describing a measurement system of instrumentation, calibration procedures, observational techniques, acceptable monumentation, network geometry, and data reduction methods, and stating permissible tolerances for a variety of measurement systems (FGCC 1984). Specifications are designed so that the results are usually 2.5 to 3 times better than the stated accuracy of the particular order and class.

The classification of a horizontal control station by order and class certifies that the coordinates of that station were determined to a specific relative accuracy with respect to the coordinates of adjacent, directly connected NGRS points in the horizontal control network. This relationship is expressed as a *distance accuracy*. Distance accuracy is the ratio of the relative distance error between a pair of control points to the horizontal separation of the two points. These accuracy classifications cover a wide range of surveying requirements, from parcel boundary surveys to super-precise global geodetic surveys for crustal motion determination.

The classification of a vertical control point by order and class certifies that the orthometric height of that station bears a specific accuracy to the heights of all other points in the vertical control portion of the NGRS. That relation is expressed as a height difference accuracy. Height difference accuracy is the relative height error between a pair of vertical control points that is scaled by the square root of their horizontal separation traced along the leveling route between the two points.

The accuracy of horizontal survey points is often expressed as if it were *absolute*, such as "plus or minus 1 foot," but this kind of statement always implies accuracy *relative to the project control framework*. Since the project may not be tied to the NGRS, or to any geodetic control framework, the statement says nothing about how accurately positioned the project is relative to other projects or to the geodetic reference framework. In this case, as in most, the statements are relative, not absolute. Statements about spatial correlation and meaningful positional accuracy of data from independent sources can only be made when all positional accuracy is relative to the same reference framework whose accuracy is known.

People often express map accuracy and survey accuracy in the same shorthand even though the two are distinct. *Map accuracy* is determined by comparing the mapped location of selected well-defined points to their "true" location as determined by a field survey. To meet National Map Accuracy Standards, 90 percent of the sample pairs of measurements—mapped and surveyed—must be within a tolerance specified in terms of inches at the publication scale. Map scale and sample size affect the determination of map accuracy. In contrast, *survey accuracy* is independent of any map scale. The accuracy of a survey is based on the specifications and procedures used. For example, if two surveyors followed the specification and procedures for a second-order, class I survey to conduct independent surveys, their results would be within one part in 50,000 of each other 95 percent of the time.

The accuracy of the geodetic reference framework for a multipurpose LIS must be sufficient to support all of the anticipated applications, the most demanding of which will be those pertaining to the land parcel. The National Research Council addressed this issue in *Procedures and Standards for a Multipurpose Cadastre,* making a distinction between systems based on the method of integrating land data:

> If the positional integrity of the land data is to be accomplished solely by graphic means—the necessary correlation being provided solely by reference to the coordinate grid shown on the maps—only the density of control ordered for the maps is required. If, however, the integration of the positional information is to be accomplished numerically, relatively high-density standards are required. Numeric integration of the data should be an essential feature of any modern land-data system, and the density and accuracy requirements of the horizontal survey control should be determined accordingly.
>
> With respect to accuracy, the determining factor will be the extent to which the control survey stations are to serve multiple purposes. Similar to the above, if the integration of the positional data is to be done graphically, a relatively low order of accuracy will be required for the horizontal control network, such as that attendant to the federal classification of third-order, class I, or second-order, class II, should be met.
>
> *(NRC 1983, pp. 24-25)*

The accuracy of the geodetic reference framework is a function of the accuracy of the points and the quality of the adjustment. Since all other spatial information in the multipurpose LIS will be hung on the geodetic framework, it is important to preserve the integrity of the network by including only points that meet minimum accuracy standards, probably third-order class or better. However, there are many surveyed points that can contribute to the value of an MPLIS even though they cannot meet this accuracy requirement. These tertiary control points may be tied to the geodetic reference framework, and coordinates for them derived from the tie. Or coordinates may be obtained in some other way, such as digitizing. Whatever the case, the multipurpose LIS database should carry sufficient information to identify the source of the survey information, and some indication of its accuracy. If coordinate values are available, the database should record their source, how they were derived, and the datum.

The FGCC classification of survey accuracy stops at third-order, and there is not a standard classification for lower-order surveys. A local classification may be used, but it should use the FGCC classification as far as it goes, and follow a conceptually similar scheme for lower-order surveys.

DENSITY

One of the major determinants of the density of a geodetic reference framework is the accuracy requirement. Until recently, the only way to connect the NGRS horizontal points for coordinate determination was through terrestrial horizontal control measurements of angles and distances, so the points had to be intervisible. A traditional first-order horizontal control network by terrestrial methods requires station spacing of 3 to 8 kilometers. Using the same method, a second-order, class I control network requires spacing of 1 to 3 kilometers. In other words, fewer stations are required for the more accurate network than for the less accurate one. The sources of random error are the reason for this. Two kinds of random error affect surveys: errors that are point specific, such as instrument centering error, and errors that are a function of distance. If highly accurate instruments and methods are used for two surveys, all other things being equal, the survey with more points will be less accurate because it has more possibilities for errors.

Another important consideration in determining the density, and also the distribution, of geodetic reference framework stations is accessibility. The National Research Council (1983) has recommended that communities require parcel and subdivision surveys to be tied to the geodetic reference framework. To require ties to a sparse network would be costly for surveyors and for their customers, so many communities have initiated densification programs and at the same time revised their ordinances to require ties to the network when a geodetic reference framework monument is within a specified distance. *"Typical recommendations range from 0.2 to 0.5 mile (0.3 to 0.8 km) between monuments in urban areas to 1 to 2 miles (1.6 to 3.2 kms) in rural areas* (Ziemann 1976, McLaughlin 1977). *We concur with these recommended densities of monumented points"* (NRC 1983, p. 24).

The geodetic reference framework for a multipurpose LIS generally uses existing the NGRS stations as the primary control points. The network is densified by tying in supplemental control stations using the appropriate FGCC specifications and procedures for terrestrial surveys, typically second-order, class II. Regardless of the methods used to establish the NGRS stations, terrestrial or satellite, actual field observations are made to tie the denser, less accurate points to the sparser, more accurate ones. Only by rigorously connecting the supplemental stations to the primary NGRS stations according to FGCC specifications is it possible to establish the accuracy of the supplemental stations and hence of the geodetic reference framework as a whole.

HORIZONTAL AND VERTICAL DATUMS

In civil engineering, a *datum* is any surface, line, or point used as a reference for subsequent measurements. These control points are identified as the datum for the project, i.e., a *local datum*. The NGRS also includes the datum concept. A *horizontal geodetic datum* provides a regular mathematical surface, called an *ellipsoid of revolution*, as a model of the Earth, upon which computations can be performed. The *vertical geodetic datum* of the NGRS is in some respects more complicated than the horizontal datum, in that the vertical datum is based on the physical concept of mean sea level. In practice, however, height values published by NGS provide the project-specific vertical starting points for a multipurpose LIS. Field survey measurements, observed on the surface of the irregularly shaped Earth, can then be reduced to equivalent values on the geodetic datum for subsequent computations. It is usually enough to see the NGRS datum as a set of numbers assigned to monumented control stations. Along with this set of numbers, the FGCC "rules" provide the instructions to properly incorporate new stations that are to be connected to the NGRS by additional field measurements.

Horizontal Datums and Coordinate Systems

Two horizontal datums are encountered in the NGRS: *the North American Datum of 1927 (NAD 27)* and the *North American Datum of 1983 (NAD 83)*, which is gradually replacing NAD 27. The horizontal North American Datum is marked by a network of about 300,000 control stations in the United States, and a large number of connected stations maintained by state and local organizations. NAD 83, which was completed in July 1986, is a new mathematical *adjustment* of the entire North American network. Adjustment in this context is the determination and application of corrections to survey observations for the purpose of removing internal inconsistencies in the derived results. Also, NAD 83 uses a refined figure of the Earth called the Geodetic Reference System of 1980 (GRS80). GRS80 is Earth-centered and approximates the Earth's true size and shape better than the Clarke spheroid of 1866, which was the reference ellipsoid used for NAD 27.

NAD 83 resulted in new geodetic coordinates for all horizontal control points in the NGRS. Coordinates within the conterminous United States have changed as much as 100 meters. The NAD 83 project to make this change was undertaken because NAD 27 values could no longer routinely provide the quality of horizontal control required by surveyors and engineers. Serious distortions in NAD 27 have been corrected by NAD 83. In many areas NAD 83 is twice as accurate as NAD 27. The change to an Earth-centered datum also accommodates the incorporation of GPS-derived coordinates, which are also Earth-centered. All positional information should include a reference to the datum used. Without a correct datum tag, invalid assumptions at a future date could result in inaccurate spatial correlation of LIS data.

NAD 83 will affect everyone who uses coordinates related to the NGRS. Everyone needs to consider the impact of NAD 83, from primary users of the NGRS, such as the geodetic surveyor performing precise surveys, to the secondary users of the NGRS that produce products such as maps that are directly connected to the NGRS, to the tertiary users of the NGRS, including anyone with coordinate-encoded data. Coordinates based on NAD 27 are only consistent with other NAD 27 coordinates. Likewise, NAD 83 coordinates are only consistent with other NAD 83 coordinates. ***With both datums currently in everyday use, coordinate users are presented with the task of transforming from one datum to another.*** Ideally, the transformation should not degrade the accuracy of the coordinates, as expressed by the order and class of the station. For example, second-order, class I NAD 27 coordinates and second-order, class I NAD 83 coordinates are each internally consistent to 1:50,000, and the aim of a transformation is to preserve this accuracy.

In 1980 NGS adopted three general approaches for transformation from NAD 27 to NAD 83 (Bossler 1983). The selection of the most appropriate approach depends on the accuracy required of the conversion, the amount of supporting data available, the resources available, and the necessity for conversion.

The relationship between NAD 27 to NAD 83 is non-linear, and transformation methods are approximations; no constant or algorithm can be applied everywhere to make the transformations. This kind of coordinate-to-coordinate transformation results in a fit between the two sets of coordinates, but does not improve accuracy. The best way to avoid degradation of coordinate information is to recompute coordinates using original source documents, including field observations. This may dictate the timing of an agency's adoption of NAD 83. In general, *it is preferable to base a new multipurpose LIS on NAD 83 from the beginning,* thus avoiding some of the possible problems associated with transformations. NGS provides consultation, publications, and one-day workshops to assist in the selection of the appropriate approach to conversion.

Latitude and longitude are the primary spatial coordinates for the horizontal portion of the NGRS. From them, a variety of plane coordinate systems can be calculated. Many users prefer plane coordinates to latitude and longitude, which are more complicated to manipulate mathematically. Map projection equations translate geodetic information about the "round" Earth onto a flat map by converting latitude and longitude to plane coordinates. This, of course, leads to some distortion of the data, but the projections are selected to distort the graphical presentation in a controlled, pre-selected manner. On maps prepared using rigorous map projections, the amount of distortion can be mathematically computed.

The national plane coordinate systems currently in use are the State Plane Coordinate System of 1927 (SPCS 27), the State Plane Coordinate System of 1983 (SPCS 83), the Universal Transverse Mercator System of 1927 (UTM 27), and the Universal Transverse Mercator System of 1983 (UTM 83). These predefined map projections are subdivided into zones, each of which is designed to cover a specific geographic region of the country. Figure 3-4 depicts the zones of SPCS 83. The regions are generally bands that are 100 to 150 miles wide and oriented either north-south or east-west. The general principle that applies to any zone is that the distortion is known and is proportional to the width of the area covered by the zone. For the surveyor, the distortions in a map, plat, or engineering drawing that are attributable to the map projection are expressed in terms of corrections to angles and distances between points. Zones are generally limited in width to keep the distortions acceptably small. If the use of a plane coordinate representation only requires conversion between geodetic coordinates (latitude/longitude) and plane coordinates (X, Y or northing, easting), the conversion computation is exact and the zone width is less important. Also, the length of a zone does not cause distortions except in extremely long zones, i.e., pole to pole. While recognizing that "a number of projections have been used as a basis for the preparation of large-scale maps," the National Research Council recommended the use of the State Plane Coordinate System for multipurpose LISs in the United States because of their universality.

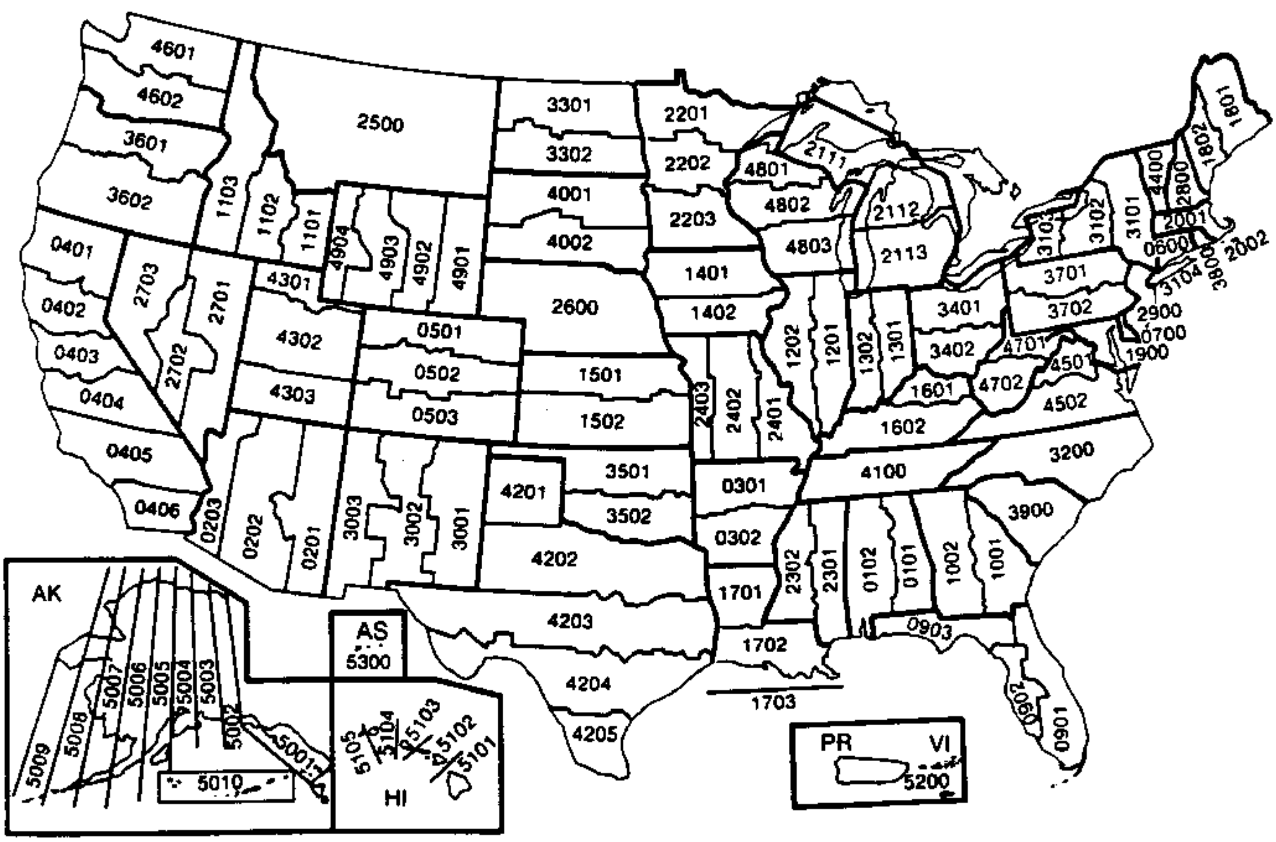


Figure 3-4: Zones of the State Plane Coordinate System.

To date, 26 states have enacted legislature specifying the use of 1983 State Plane Coordinate System. Forty-two states had enacted SPCS 27. In addition to providing the mathematical definitions of SPCS, these state laws define standards to be used in making connections to the NGRS. Mandatory use of SPCS is not the purpose of the laws, but restrictions on the number of coordinate systems commonly used in a state is wise. The laws were generally sponsored or supported by state professional surveying and engineering societies and state agencies (Stem 1989). Regardless of the existence of a state law or its content, SPCS is generally acknowledged to be the "official" plane coordinate system for local maps, and other, mid-scale mapping series, such as the U.S. Geological Survey (USGS) 1:24,000 scale topographic series, also use SPCS.

Vertical Datums of 1929 and 1988

The vertical control portion of the NGRS is based on a national reference surface called the National Geodetic Vertical Datum of 1929 (NGVD 29). Unlike the horizontal datum, which is a purely mathematical surface, the vertical datum (NGVD 29) is based on the *geoid*. The *geoid* is defined as the equipotential surface of the Earth's gravity field which best fits mean sea level (NGS 1986). NGVD 29 contains about 585,000 permanently monumented vertical control bench marks connected by geodetic leveling. These bench marks provide the primary vertical control for United States civilian surveying and mapping operations. Geodetic leveling observations are processed through rigorous adjustments to determine orthometric heights of known accuracy referred to NGVD 29. In this way, all bench mark heights published by NGS can be directly compared to determine differences in height between bench marks.

As was the case for the NGRS horizontal stations, NGS has undertaken a new adjustment of the bench marks in the NGRS. The new adjustment and redefinition of the vertical datum, called the North American Vertical Datum of 1988 (NAVD 88), is scheduled for completion in 1990-91 (Zilkoski and Young 1985). While bench mark heights, in an absolute sense, may change by as much as 2 meters from NGVD 29 to NAVD 88, height differences between nearby bench marks will change by only a few millimeters, which is not significant for the accuracies required by a MPLIS. In crustal motion areas, height differences may change on the order of centimeters to reflect improved, up-to-date height values for surveying, mapping, and other engineering applications. In addition, NAVD 88 will provide an improved basis for better geoid height determinations. These are needed to convert Earth-centered GPS-derived heights to the orthometric heights published by NGS. GPS does not measure orthometric heights directly. This aspect will become more critical in the future as more and more surveyors take advantage of GPS technology.

PRODUCERS OF GEODETIC REFERENCE FRAMEWORK DATA

A geodetic reference framework is a composite of geodetic information provided by many producers. NGS supports the NGRS, a database containing information about control stations with the highest order of accuracy. The NGRS contains information on horizontal and vertical stations established by NGS, as well as stations established by other public and private agencies following rigorous field and documentation procedures. Contributors to the NGRS submit their survey records to NGS according to the prescribed NGS input format known informally as *Blue Book* format (FGCC 1989). If the data are accepted, the stations are mathematically integrated into the NGRS. The composite of all the NGRS-connected data yields the geodetic reference framework foundation for LIS.

The NGRS stations generally constitute the primary control network for a multipurpose LIS. The process of developing a geodetic reference framework of integrated data begins with an inventory of all potential sources of survey records. Surveys by Federal, state, and local government agencies, utilities, and private companies can be a valuable source of supplementary control, but they have not necessarily been integrated into the NGRS. To create a single, integrated geodetic reference framework, the implementing agency should collect these survey records and submit them to NGS, who will analyze them for accuracy, density, distribution, and compatibility and to determine whether or not the stations have been properly connected to the NGRS. Those that meet the requirements are then incorporated into the NGRS. At that point, coordinates can be calculated for the stations.

At the state level, leadership in the establishment and maintenance of geodetic control is often provided by the Department of Transportation or Department of Natural Resources. In some states, the Secretary of State, or the State Surveyor maintains records of geodetic control. Field data from these agencies have not necessarily been sent to NGS for incorporation into the NGRS, but the survey information should be sought and analyzed for inclusion in the geodetic reference framework. FGCC standards and specifications may have been used. If not, additional effort may be required to integrate the data into the NGRS. At the local level, private surveyors, engineers, and utility companies often establish geodetic control in response to project-specific requirements. In some areas, there are public surveying offices. At the local level, a surveyor's office may not be able to provide the data, but may direct the user to the source. Often the local public works or highway department will have a surveying component. In these offices, project-specific coordinates and local control systems will be more prevalent.

Records of the horizontal and vertical portions of geodetic reference frameworks may be maintained separately. Some agencies, particularly those concerned with water resources, emphasize the vertical framework, such as, at the Federal level, the Federal Emergency Management Administration (FEMA), Environmental Protection Agency (EPA), and Coastal Zone Management Agency. Transportation departments may have considerable control data. These valuable sources of survey records should not be ignored in the initial development of a geodetic reference framework. The costs of the surveys have already been paid, and incorporating them into the reference framework extends their utility by making them available to users directly and as the foundation for a multipurpose LIS. Ideally, procedures would be enacted to incorporate new survey data into the geodetic reference framework periodically.

CONCLUSIONS

The geodetic reference framework described in this chapter is the foundation for a multipurpose land information system. By establishing an accurate framework, and then accurately relating land information to it, we create a pool of compatible information on which to base decisions. The accuracy requirements of this framework should be established based on the most stringent requirements of the system. The multipurpose LIS is not only a map; it is a system to "improve land-conveyance procedures, furnish equitable taxation, and provide much-needed information for resource management and environmental planning" (NRC 1980). With its focus on the parcel, the multipurpose LIS should support all of the requirements of land records, and its foundation, the geodetic reference framework, should be designed to meet these requirements, which are more demanding than those of mapping.

Single-purpose control is usually uneconomical in the long run because it is not consistent with other project-specific control systems for future applications. If the spatial relationship between adjacent projects is needed, their position, scale, and orientation must be stated with respect to common, compatible control. The control exists in a geodetic reference framework in the form of permanently monumented stations whose locations are accurately measured and mathematically described, relative to a common datum. Such accurate geodetic reference frameworks provide the most cost-effective spatial foundation for compatible, accurate land data, whether in map or in digital form. While local compatibility may be all that is needed for decisions involving a single, primary activity, users at a higher level, such as planners, investors, developers, and decision-makers in the regulatory process, must be able to relate independent sets of information and find that this type of data cannot be used in its existing form. These activities and decisions require large amounts of diverse types of spatial information, cutting across a large number of primary activities. When spatial data share a geodetic reference framework, they are spatially compatible.

The demand for compatibility among otherwise independent spatial information products makes the use of a single geodetic reference framework a source of economic value in a multipurpose LIS. The use of geodetic reference frameworks as the foundation for a multipurpose LIS ensures that the needs of those operating within a single activity or organization will be met, and more importantly, that the data generated by each activity can be used by others. The user can then use different data sets together to serve as the basis for reasonable decisions without additional data collection or expense.

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APPENDIX 3-1
SURVEY ACCURACY CLASSIFICATIONS

HORIZONTAL SURVEY ACCURACY CLASSIFICATIONS

Distance accuracy, 1:a, is computed using the formula a = d/s, where d = the distance between two points and s = the propagated standard deviation of that distance. The variable s is computed using an error propagation model that takes into account the design of the survey network and the accuracy estimates of the field measurements.

Classifications	Minimum distance accuracy, 1:a
Order A	1:10,000,000
Order B	1:1,000,000
First-order	1:100,000
Second-order, class I	1:50,000
Second-order, class II	1:20,000
Third-order, class I	1:10,000
Third-order, class II	1:5,000

GEODETIC LEVELING ACCURACY CLASSIFICATIONS

Height difference accuracy, b, is the relative height error between the two points, where $b = S/\sqrt{d}$, d = horizontal distance in kilometers between the two points traced along the leveling route and S = propagated standard derivation of height difference in millimeters.

Classifications	Maximum height difference accuracy, b
First-order, class I	0.5
First-order, class II	0.7
Second-order, class I	1.0
Second-order, class II	1.3
Third-order	2.0

(from FGCC 1984, 1988)

APPENDIX 3-2
POTENTIAL SOURCES OF SURVEY DATA

Agencies that have had geodetic surveys incorporated into the NGRS:

- U.S. Geological Survey (Department of the Interior)
- Bureau of Land Management (Department of the Interior)
- Forest Service (Department of Agriculture)
- Federal Highway Administration (Department of Transportation)
- Soil Conservation Service (Department of Agriculture)
- U.S. Army Corps of Engineers (Department of Defense)
- U.S. Department of Housing and Urban Development
- National Aeronautics and Space Administration
- Tennessee Valley Authority
- International Boundary Commission
- Defense Mapping Agency

Potential sources of geodetic data are:

- National Geodetic Survey
- Bureau of Land Management
- U.S. Geological Survey
- Other Federal agencies
- State agencies such as Department of Transportation, Department of Natural Resources
- County agencies such as Public Works Department, Engineering Department
- City agencies
- Utilities
- Private firms

APPENDIX 3-3
NGRS PRODUCTS AND SERVICES CONTACTS

To order the NGRS data products, contact:

National Geodetic Information Branch
N/CG174, Rockwall Building, Room 24
National Geodetic Survey, NOAA
Rockvillle, Maryland 20852
Telephone: (301) 443-8631

For information on the NGS workshop program, contact:

Mr. Edward J. McKay
N/CG13, Rockwall Building, Room 313
National Geodetic Survey, NOAA
Rockville, Maryland 20852
Telephone: (301) 443-8567

For information on the Federal Geodetic Control Committee, NGS state advisor program, or other NGS programs, contact:

Mr. Gilbert J. Mitchell
N/CG1x10, Rockwall Building, Room 622
National Geodetic Survey, NOAA
Rockville, Maryland 20852
Telephone: (301) 443-8143

4 LAND INTERESTS

Earl F. Epstein and Patricia M. Brown

In Chapter 1 we introduced the central themes of the *Guidebook:* the multipurpose land information system (MPLIS) and the vision for improving the nation's land information. Some of the most basic information about land, and much of what local governments want to include in an MPLIS, concerns *land interests*. Ownership, zoning, rights-of-way and easements, political jurisdictions, taxation—each of these is an example of a particular *interest in land*, defined in terms of *nature* and *extent*. The nature of an interest in land refers to the rights and restrictions affecting the use of the land and its resources. The extent of land interests refers to the boundaries of those interests in space and time. In this chapter, we describe land interests in the United States, how they have evolved over time, and how they have shaped our land records systems. In Chapters 5 and 6 we focus on the extent of land interests, and specifically on parcel boundary descriptions.

CHANGING CONCEPTS OF LAND

Our concepts of land and interests in land have evolved over many centuries. In English feudal society, the relation between people and land was fixed. At all levels of society, services and duties were exchanged for the use of land. The sovereign granted lords of the manor control over the use of land in exchange for military support when needed, and the lords, in turn, allowed others to use the land in return for military service and foodstuffs. No one could sell the land, nor could they easily relocate.

Technological advances brought agricultural surpluses. A class of merchants and entrepreneurs came into being, along with a monetary system. Money began to substitute for prescribed services and duties. Under this new form of *tenure*, individuals gained greater control over land relative to their feudal superiors and demanded freedom in the private defini-

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tion of rights in land. One of the most famous examples of this transition is the Magna Carta, signed in 1215, the second item of which took from the king and gave to the barons the right to determine who would inherit an estate when a baron died.

The post-feudal practice of privately defined and controlled land interests was transported to America. Through the 18th Century and into the 19th, the American concept of land was based upon a stable agrarian society. Thomas Jefferson described, based on the political philosophy of John Locke, a society of small land holders where land was widely distributed in order to widely distribute political power. Land was measured, divided and distributed in family-sized parcels to many private citizens who decided how to use it. Land transfers were infrequent, people had a direct, personal relation with the land, and the value of land was closely linked with its agricultural potential.

With the industrial revolution, the concept of land ownership rights expanded to encompass other uses in addition to agriculture. Land transfers were more frequent, and people began to treat land as a commodity, the value of which was set by the market. Governments derived revenues from a property tax usually based on this *market value.*

This concept of land persists into the 20th Century. However, 20th Century society increasingly recognizes that land has value that derives from aesthetics, ecological function and other characteristics and uses of the land *even when these are not reflected in the market value.* This recognition often comes in the form of legislation that directly or indirectly controls the use of land. Examples at the federal level include the Food Security Act of 1985, the Clean Water Act, and the Clean Air Act. At the state and local levels a wide variety of laws and procedures restrict the uses of land that contains resources ranging from wetlands to farmlands, from vistas to historic areas. These laws are an alternate expression of demand, and the public interest in land they create overrides and limits private interests.

THE BUNDLE OF RIGHTS

The ownership interests associated with land are like the sticks shown in Figure 4-1, with each stick representing a right or an interest in land. In modern society the number and variety of interests in land is considerable. Traditionally, the largest and best recognized collection of privately held rights are those associated with *fee simple absolute ownership,* also called *fee simple,* or just *fee,* referring to what most of us think of as the rights of private land ownership. Alternatively, one person may own rights to use the land surface, another the minerals below the surface, another a lease, and another a mortgage. Overriding these interests are public interests, such as the right to tax, the right to navigate, the right of eminent domain, and the more recently emerging rights to limit the use of land in order to protect the common health, safety, and welfare.

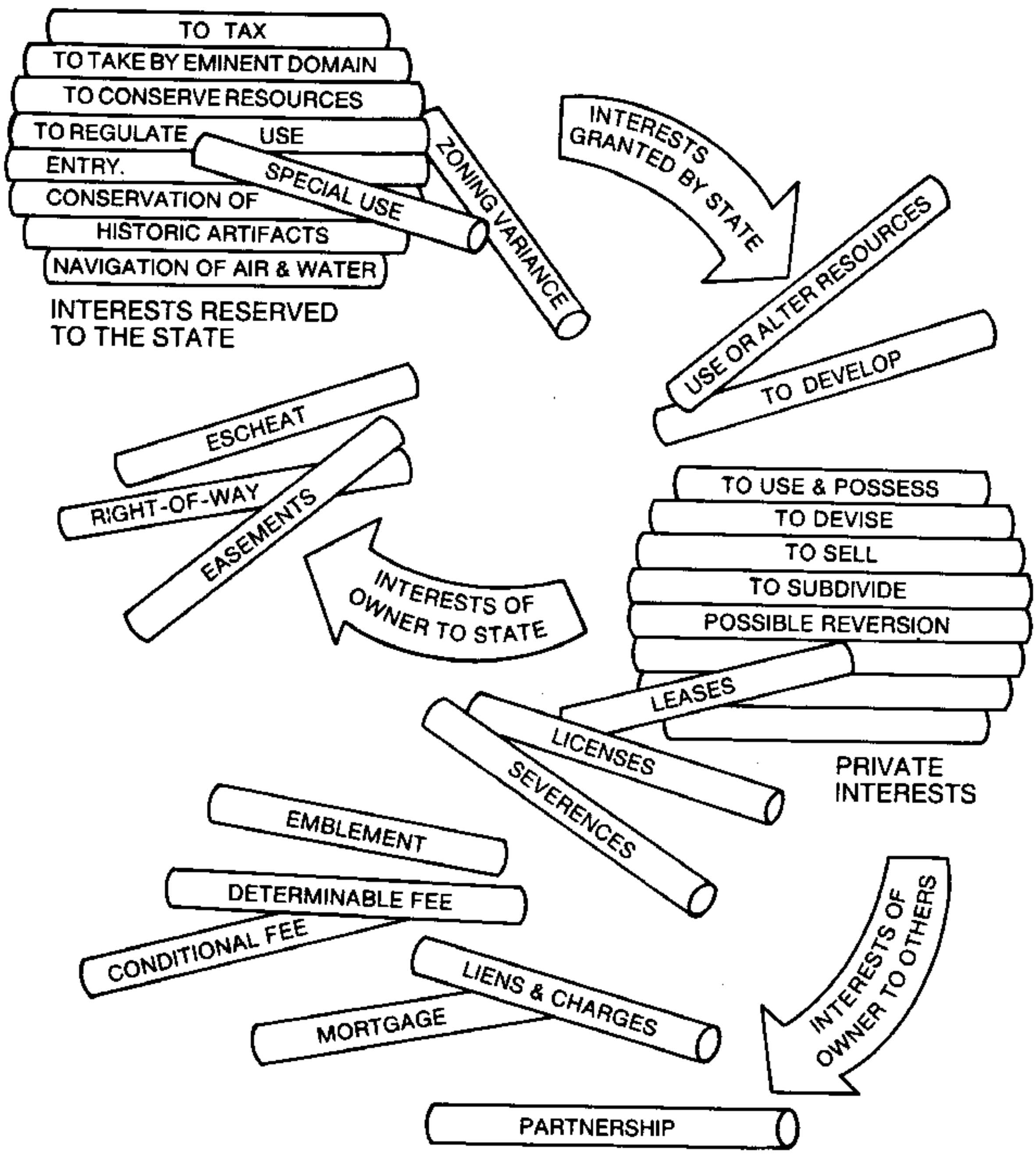

Figure 4-1: The Bundle of rights or interests is dynamic.

The Battle of the Peace River

In 1977, Coastal Petroleum, one of the firms digging West Central Florida's rich phosphate deposits, sued competitor Mobil Mining & Minerals in Polk County Circuit Court. Coastal's claim against Mobil was staggering: $2.5 billion in damages for taking phosphate from state land where Coastal said it held mineral rights.

The suit had its roots a century earlier, when the natural resources of Florida, a swampy, sandy, prickly place that puzzled and frustrated its conquerors, were valued mostly for their income potential. Land was plentiful and cheap, much of it under water much of the year. The state gave away millions of acres of the swamps or sold it for as little as a quarter an acre, to induce the Northern rail and industrial barons to make the boggy peninsula sprout crops and commerce.

Some of the state's inheritance of land was not to be given away. The navigable waters were held as a public trust—a principle drawn from English common law.

So, too, was the land immediately along the rivers, from the channel out to an imaginary line where the highest water during summer floods would ordinarily reach. That, the argument went, was the real extent of a river. Where to draw the ordinary high-water line, which defined the area of state ownership, was pretty much anybody's guess since early Florida surveys are notoriously unreliable—or fraudulent.

By 1941, the state was leasing its land instead of giving it away. Along the Peace and Alafia rivers, two streams in Central Florida, Coastal Petroleum got the rights to mine phosphate within the area the state said it owned. The suit was filed after Coastal discovered that Mobil had been mining the same land.

Mobil came back with its own set of old papers. One was a hand-written deed, signed June 13, 1881 for the same land the state and Coastal later claimed. Mobil had bought the land and mined the phosphate and paid the taxes. For that, they were now being sued for $2.5 billion, and they intended to defend themselves.

In vigorously pursuing that defense, Mobil would inevitably bring up a bothersome little side issue: through the land in Mobil's deed, the Peace River flowed. But Mobil's deed didn't mention it—as if the river itself had been sold with the land.

Mobil said the Peace River did not belong to the people of Florida. It belonged to Mobil Oil Corp.

Mobil's claim on the Peace meant the people of Florida were now a party to the conflict. Florida's grab bag history of land and money was littered with thousands of deeds such as Mobil's. Might the state lose its claim to its lakes and rivers because a century ago, overzealous boosters, relying on erroneous surveys, had unwittingly sold them off? Did the public retain its inheritance, regardless of yesterday's mistakes?

In 1982, Mobil sought to settle the questions. It sued the state to win undisputed title to the Peace River land. Coastal dropped out of the legal tangle in January 1987, but by then the state had jumped in, seeking $60 million from Mobil for mining on state land—the same land Mobil said it owned. Both sides hoped for a precedent that would determine, in this case and others to follow, how much land along rivers the state could claim—or which rivers might actually be private property. Their mission was to seek two fundamental truths: the history of boat traffic on the Peace River, to prove navigability, and the highest point the water would ordinarily reach, to define the extent of state ownership. Those were the narrow issues around which the trial would revolve.

In November 1987, the lawsuit was settled out of court in favor of the State of Florida, based on the State legal team's documentation of the wreck of a barge in the Peace River. One of the stipulations of the settlement was that "the deal could not be cited as a precedent in other state land disputes."

The above is an extract from "Keeping the Peace" written by Randy Loftis and published in the February 26, 1989 issue of Tropic, the Sunday Magazine of the Miami Herald. Randy Loftis is a staff writer with the Miami Herald.

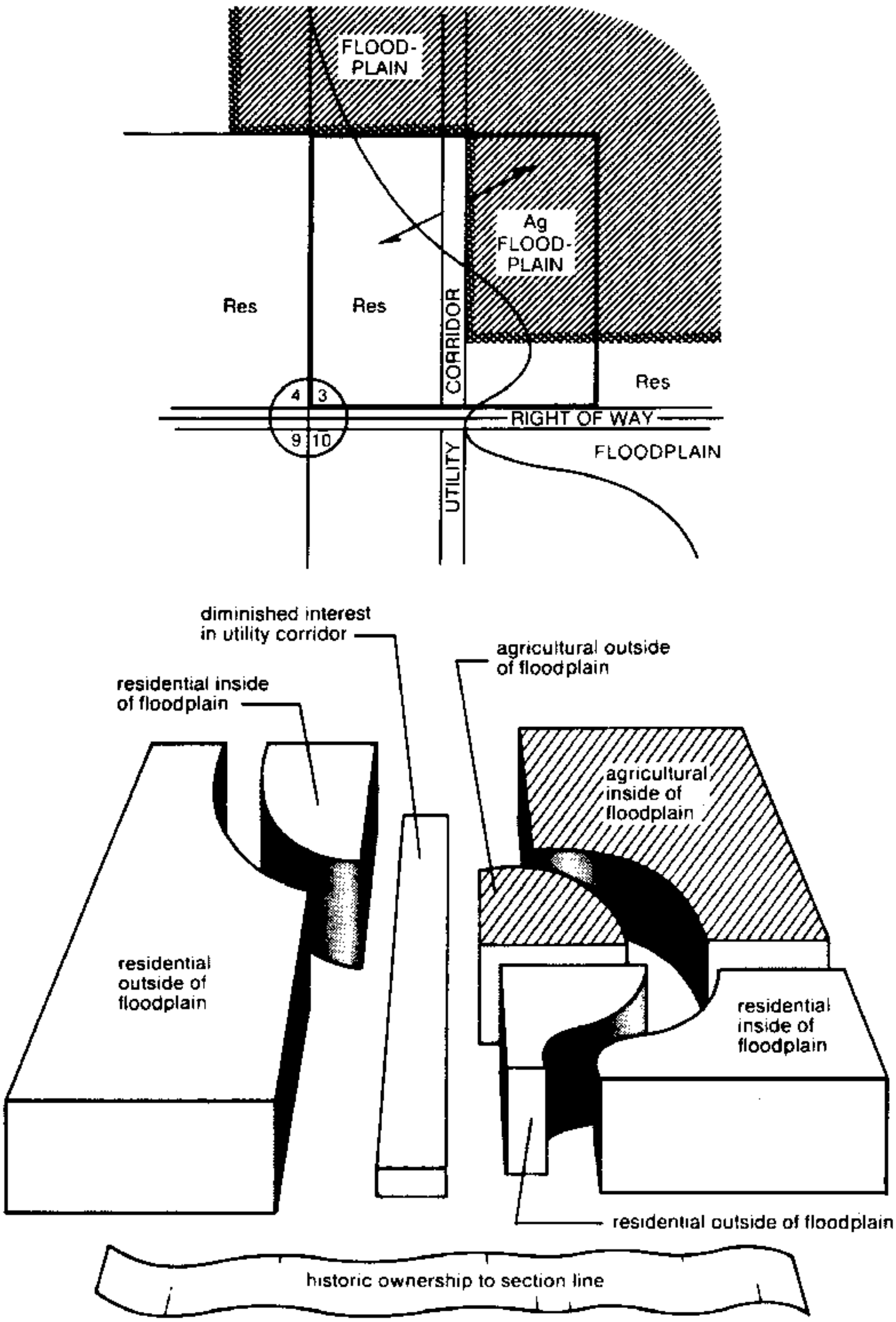

Figure 4-2: Land interests fracture the parcel.

The list of the rights and interests associated with land seems to be unlimited; individuals and society continually create new ones. Air rights, for example, were not made explicit until technology made it possible to use the space above a piece of property separate from its use at ground level. Similarly, the public interests in protecting the ecological function of wetlands and the productivity of farmland have been articulated only during the last thirty years or so.

The bundle of rights paradigm successfully represents the complexity of land interests. This complexity is reflected in records of land interests, which incorporate traditional concepts of the land parcel. Most of us think of the land parcel in terms of ownership, or as the unit of land described in property surveys and subdivision plats. However, many interests in land *fracture* this parcel or extend to many parcels, as shown in Figure 4-2. Information about the nature of the interest cannot always be ascribed to a particular parcel. The information is at the *parcel-level,* but it is not necessarily *parcel-based. The ideal MPLIS would record the nature and extent of all public and private land interests and would provide the capability to retrieve information about these interests for any land area.*

THE DIMENSIONS OF LAND INTERESTS

Property boundary descriptions in commonly held records are usually limited to a narrow subset of interests, such as fee simple and easements. The property description usually specifies only two dimensions of a unit of land; how these are described is the subject of Chapters 5 and 6. There are other dimensions to land interest parcels today however, and improved land information systems must accommodate their description in some way.

AIR AND SUBSURFACE RIGHTS

Air, or *superjacent,* rights are associated with the use of space above a piece of property. *Subsurface,* or *subjacent,* rights are those associated with the use of space below the surface. Originally, the owner of a parcel of land held all the rights to the use of the space, and the resources within it, demarcated by planes from the center of the Earth through the boundaries and upward. In some cases, superjacent or subjacent rights have been sold by their owner, in exercise of the privilege of *free alienation.* In other cases, limitations on the exercise of these rights have been changed through public actions. One example is the modification of air rights to accommodate air traffic. Figure 4-3 illustrates the dimensions of land interests.

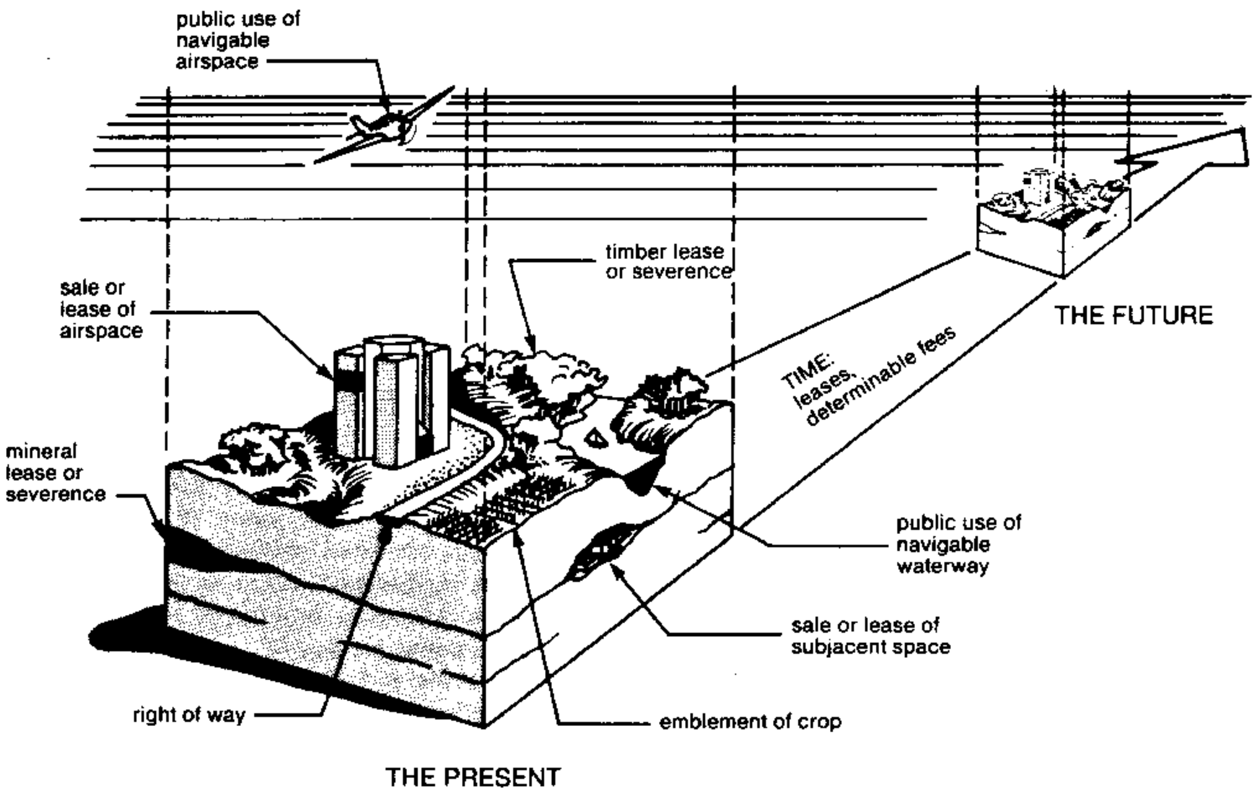

Figure 4-3: The dimensions of land interests.

TIME

Land interests may be limited in time as well as in space. For example, a *life estate* gives use of a land parcel for the life of a particular person. Others are limited to the indefinite period during which a prescribed use exists, and others are limited to a repeating period of time, such as with a time-share unit.

CHARACTERISTICS

Land rights may be granted or restricted according to the presence or absence of specific characteristics, rather than by specific descriptions of location or time. This technique is often used in legislation designed to protect environmental or cultural resources. For example, legislation might limit the uses of wetlands based on the soil or vegetative characteristics. Implementation mechanisms then depend upon the identification of these lands at the parcel level. Similarly, flood plain legislation typically limits the uses of land below the elevation of the 100-year or 50-year flood, but that elevation depends on permeability of soil or land cover, climate and other characteristics of the watershed, and may change if those characteristics are altered. The area affected by the legislation is often poorly identified.

EXISTING LAND RECORDS SYSTEMS

Transfer of land to private ownership was recognized as a basic function of government during the settlement of North America. The institutions for recording land interests in the United States developed at that time (NRC 1980, p. 7). Underlying our recording systems is the *principle of public notice,* i.e., that documents affecting land interests should be recorded in a public place and available for inspection.

> The early North American cadastral arrangements were designed to promote quick, efficient, and secure land settlement. The alienation of public or crown lands, as a means of inducing European emigration, was from the outset recognized as a basic function of government in the English colonies. In support of this policy, three uniquely North American land-record tools were developed, the American recording system, the commercial abstract, and the public-land survey system (albeit, the latter was only developed in the western portion of the continent).
>
> English land-conveyancing practices at the time of the American colonization were dominated by two characteristics:
>
> First, the substantive law has reached its technical worst, and second, the structure of institutions and practices employed were still fluid, relatively undeveloped, and in a state of transition and experimentation (Payne 1961).
>
> As a result, the colonial land-record systems that evolved in the New World were a strange mixture of old English private conveyancing practices and some entirely new institutions. Among the English practices adapted were the concept of a conveyancing profession and the abstract of title. These were blended with two new institutions, the American recording system and the commercial abstract. The form of the American recording system was first described in the early seventeenth century recording statutes of the Plymouth, Massachusetts, Virginia, and Nova Scotia colonies. These statutes had four characteristics that persist today in the deed-recording laws of the United States and the eastern provinces of Canada:
>
> 1. The instrument of transfer, such as deed and mortgage documents, must be acknowledged before a public official before recording;
> 2. The entire instrument must be recorded;
> 3. Legal priority is generally assured the grantee by the act of recording; and

4. The instrument is operative without recording, with the title passing before the instrument is recorded.

NRC 1980, pp. 7-8

In the United States records that describe the transfer of interests are generally maintained at the county level, except in Connecticut, Rhode Island, and Vermont, where the city and town governments perform that function (NRC 1980, p. 17). Most land records systems have remained essentially unchanged since they were established. They were designed simply to record deeds and documents bearing on interests in land:

> . . . the land tenure system presently used in the United States is a rudimentary deed registration system, negative in nature and formulated to fit a rural, agrarian society. As land and building development exploded across America, with its attendant public controls and successive transfers of title, public registries became crowded with those who needed information about the land. Owners, buyers, realtors, investors, conveyancers, conservationists, census takers, utility personnel, among others, literally nudged one another in small areas to absorb and chronicle information about the land.
>
> *NRC 1980, from Fenton 1976*

The public records may be more or less *incomplete* over time, depending on law, historical conditions and events, and the practices in all the various professions involved. The recordation of title documents is voluntary, while recordation is designed to provide protection through public notice, the transfer occurs regardless, and rights may be created with or without records. For example, easements have often been granted privately and informally. Even those held by local government, such as drainage and access easements may be unrecorded. Recorded or not, these are valid land interests. Further, the records may contain *incorrect and mutually contradictory information* that remains undiscovered until a problem is revealed by a search of the record.

Public records that must be considered as evidence in an examination of land interests are administratively and physically scattered among many agencies and levels of government. Because they are scattered, the records are often *redundant,* as similar information is required in various offices. Because of limited and cumbersome indexing and cross-indexing they are *functionally inaccessible.* For example, most local title records systems store documents in chronological order, maintaining one or two indexes, a *grantor/grantee index,* i.e., an index of the names of buyer and seller. The index refers to the location of copies of the document in bound volumes (book-and-page) or other media, such as microfilm. Some systems also maintain a *tract index,* which cross references the location of documents with the location of the land on which they bear. The location of land in a tract index is indicated by large areas, such as section, township and range, subdivision, or tract. These systems are convenient for the storers of records, but not necessarily for their primary users. The records systems serve other potential users even less well because *the records cannot be efficiently gathered, correlated, or aggregated within or between agencies, departments, and levels of governments.* This concept is illustrated in Figure 4-4.

SECURITY OF INTERESTS

A system of assuring *security of interests* has evolved in parallel with our land records systems. The institutions that maintain public records generally do not evaluate the substance of the documents submitted to them. That responsibility lies with the users. When individuals, groups, and institutions acquire a land interest, they generally require assurance that, once the transaction is complete, no *superior claim* exists that would nullify the transaction or reduce the new owner's interest. The most basic form of guarantee is the seller's personal warrant that the interests conveyed to the buyer is the set actually owned by the seller. The seller agrees to indemnify the purchaser for any monetary loss suffered by the purchaser should there be a defect in the ownership of any conveyed interest. The purchaser is not guaranteed against loss of the interest, but he may recover the value of the interest. The seller's warrant was practical at a time when transfers were infrequent, when people knew one another, and knew the land. We are long past such a time, and new methods of securing interests have developed to reflect current conditions.

Because the public records are scattered and incomplete, and because using them is time consuming, private institutions and professions have evolved to search and examine the evidence of land interests. Title abstracters search the public records and provide a *title abstract* of the chain of title, which lists the recorded documents that apply to a parcel and summarize their contents. The *chain of title* is the series of recorded documents covering the time from the present back to the original government grant or patent or a specified period, such as 40 years. (The abstracter may build his lists to a point where they cover most of the parcels in an area and are probably more readily used than the public records. These abstracter records are private, however.) The abstracter guarantees that the abstract accurately reflects what is in the

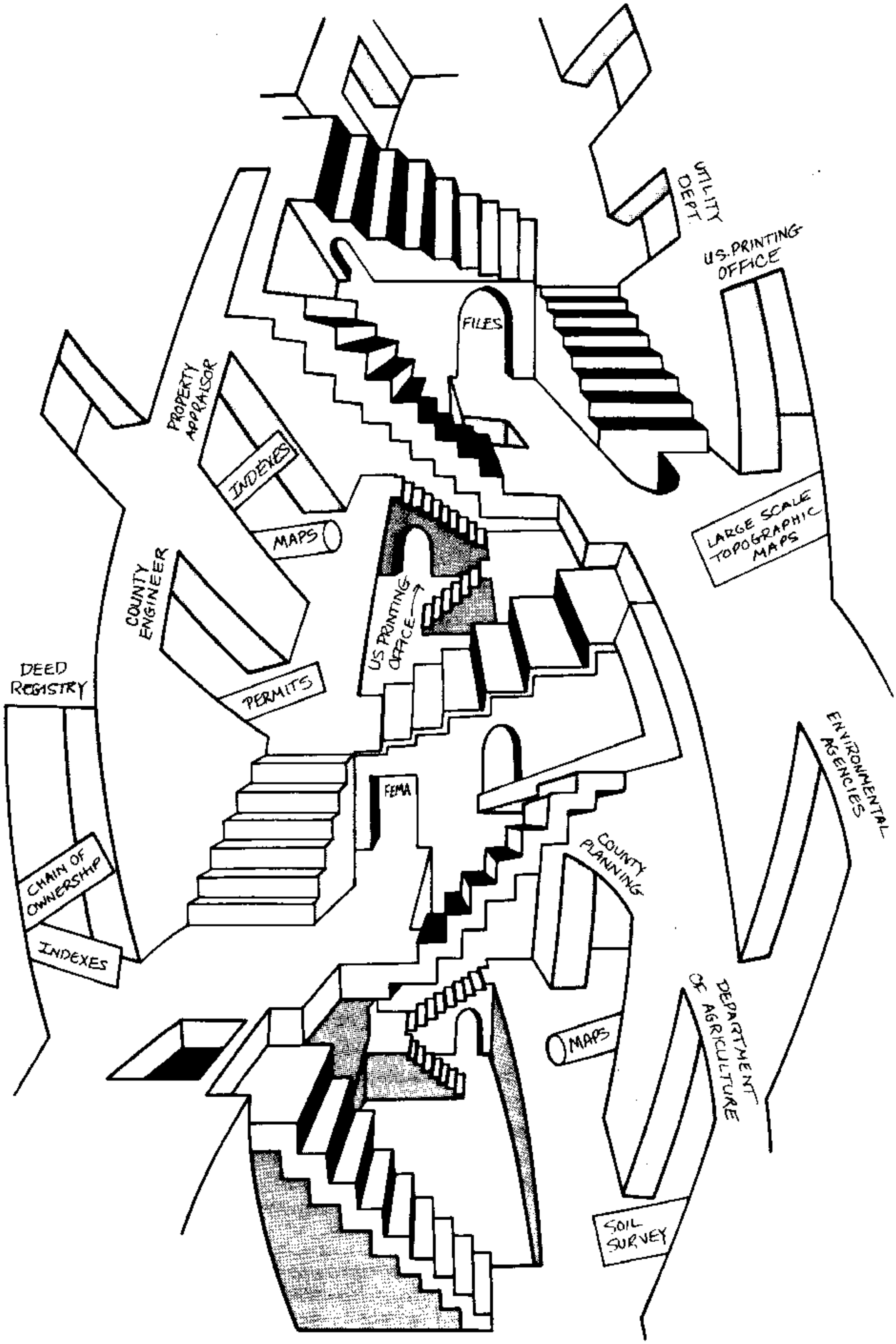

Figure 4-4: Existing records are functionally inaccessible.

public record. The abstracter does not guarantee that the public record is complete, nor does he render an opinion on the meaning of the records and their content.

The records listed in the title abstract are evidence of ownership; whether or not the evidence is sufficient to prove ownership is a matter of judgment. Parties to a land transfer who require greater assurance of ownership may obtain an *attorney's opinion.* A lawyer knowledgeable in land and other pertinent law, such as corporate, probate, bankruptcy, and divorce law, analyzes and interprets the legal significance of the documents in the chain, and offers an opinion about the status of the interest ownership. The attorney's opinion, which is still the principal method of assurance in some places today, guarantees against the negligence of the attorney, but his liability is often limited to the facts presented in the abstract, and excludes "fraud, forgeries, or acts of omission not of record" (Brown 1981, p. 325).

As transfers became more frequent, and as more land purchases were made at distances far from the land and far from the locally knowledgeable title attorney, a system of title insurance was added. Companies have arisen that not only prepare the abstracts and the opinions, but also assume the risks for a broader set of errors than that for which the title attorney is responsible. The mortgage loan business now relies on title insurance companies, which offer protection against a variety of record-based risks and also against risks not disclosed in the public records. The scope of the assurance depends upon the particular assurance policy, and can extend to coverage of boundary errors and conflicts.

These arrangements have all arisen to provide assurance to a buyer regarding the nature of the land interest acquired, its extent, i.e., location, size, shape and duration, and the status of his interest. They do not, however, provide government assurance of ownership. In contrast, in the Torrens system the state issues a government assured statement of ownership, the *registered title* (see Box 4-3). Most Torrens systems and the Massachusetts Land Court are examples of *judicial solutions,* that is the courts examine the evidence and determine the status before registering the title. (The Massachusetts Land Court also guarantees the boundary.) The Wisconsin Assessor's Plat provides *administrative solutions* that do not involve the courts before registering the title.

The Torrens system, developed in Australia and adopted in England, parts of Canada, parts of the United States, and Puerto Rico, requires registration of the title, as opposed to registration of evidence of title. The State, in turn, guarantees the sufficiency of title. Although many states in the United States passed enabling legislation, the Torrens system has not been widely implemented because of the costs of clearing all questions of title before registration, and the need to establish an indemnity fund to back up the guarantee of title. The Massachusetts Land Court, established in 1899, is similar to the Torrens system but guarantees both boundary and titles after 90 years of voluntary registration, and about 15 percent of the land area of the state has been registered.

SUMMARY

Our concepts of land and interests in land have evolved over many years and continue to change to accommodate changes in society. By the 19th Century, the market replaced agricultural potential as the measure of the value of land. In the 20th Century, other sources of value have been recognized, such as aesthetics and ecological function, and are reflected in legislation as a public interest.

The types of land interests are almost unlimited; new ones are added as society needs them. And while the most common collections of land interests, such as fee simple ownership and easements, are generally described in two dimensions, all interests have depth and height and a dimension in time. Also, land interests may be described in terms of characteristics, such as "within the 100 year floodplain" or "wetland," without simultaneously describing its spatial or temporal dimensions.

In the United States records of land interests are maintained primarily at the county level. The systems that house these records have changed little since their inception. As a whole the records are incomplete and often contain incorrect and contradictory information. At the local level they are often redundant and difficult to use, especially for planning and land management.

The public records systems are repositories of information. The status of ownership and the location of boundaries are a matter of judgment. The seller's warrant, the title abstract, the Attorney's opinion, and title insurance are all methods that have been used to provide some assurance of the nature and extent of the land interest being conveyed. Torrens, the Massachusetts Land Court, and the Wisconsin Assessor's Plat are examples of institutional arrangements that provide a government guarantee of title.

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APPENDIX 4-1
LAND INTEREST TERMINOLOGY

Appurtenant easement: an easement that "runs with the land," that is, that continues to encumber the servient estate, and to enhance the dominant estate even in the event of title transfer (SCWRC 1989).

Condemnation: the process by which property of a private owner is taken for public use without his consent, but upon the award and payment of just compensation.

Deed of Trust: similar to a mortgage, a deed of trust by which legal title to real property is placed in one or more trustees (Black 1968, Brown 1986).

Defeasible Title: one that may be annulled or made void, but which is not already void (Black 1968).

Easement: a nonpossessory, irrevocable right to use a particular piece of property generally specific to a particular use. Usually refers to an appertenant easement (SCWRC 1989).

Easement in gross: an easement that attaches to an individual rather than to the estate, such as an easement to fish or hunt on a parcel of land (SCWRC 1989).

Eminent domain: the power to take private property for public use (Black 1968).

Estate: the interest which anyone has in lands or in any subject of property. Often classified by time of enjoyment, e.g., life estate, estate for years, estate at will (which may be terminated at any time). Estate in fee, or estate in fee simple absolute, is the most absolute of land interests and is theoretically infinite in duration (Black 1968, SCWRC 1989).

Fee or fee simple: see *estate* and *fee simple absolute.*

Fee Simple Absolute: ownership of land with unrestricted right of disposition; the most common type of ownership (SCWRC 1989).

Fee Simple Defeasible: ownership of land with same rights as fee simple absolute, except that title may be annulled or lost on the occurrence of a contingent named by the grantor, e.g., grantee may be limited to or prohibited from certain uses (SCWRC 1989).

Incorporeal right: a right which is attached to and belongs with some greater and superior right, which passes as incident to it and is incapable of existence separate from the superior right.

Joint Tenancy: property interest held by two or more persons. Upon the death of a joint tenant, ownership of the share passes to the other joint tenants. Joint tenants share as a group the authority for determining the land and its resources. Each joint tenant has the right of quiet enjoyment of the property (SCWRC 1989). (See *tenancy in common.*)

Land under navigable waterways: under common law, the land under navigable waterways belongs to the public. The definition of the boundaries of the waterway vary: mean high water, high water, ordinary high water (SCWRC 1989). (See also *navigable waterways.*)

Leaseholds: an interest created by a contract for the use and possession of lands, buildings, or other property for a specified period of time and for fixed payments; an estate for a fixed term of years. Leaseholds generally convey only limited authority over the use and disposal of the property and its resources (Black 1968).

Licenses: revocable permission to use a piece of property. Licenses do not "run with the land," but instead terminate with the transfer of the title. They may be revoked within certain limits and are limited to the specified uses of resources. Permission or authority to do a particular act or series of acts on land of another without possessing any estate or interest therein (Black 1968, SCWRC 1989).

Lien: a charge, security, or encumbrance upon property to secure a debt (Brown 1986).

Mortgage: a lien on real property giving the loaning party the right to sue for title and possession of a piece of real property (Brown 1986). An estate created by a conveyance absolute in its form, but intended to secure the performance of some act, such as the payment of money, and the like, by the grantor or some other person, and to become void if the prescribed terms are not met (Black 1968).

Navigable waterways: the interpretation of the term navigable waterway varies. (See also *land under navigable waterways* and *ownership of navigable waterways.*)

Navigable water of the United States: waters are "navigable water of the United States" when they form in their ordinary condition by themselves, or by uniting with other waters, a continued highway over which commerce is or may be carried on with other states or foreign countries in the customary mode in which such commerce is conducted by water (Black 1968).

Navigation rights: the public right of navigation and passage over all water deemed navigable. Therefore, the government has the right to prevent obstruction, appropriation, or alteration that would impede or prevent navigation. (See *navigable waterways.*)

Ownership of navigable waterways: under common law, and sometimes statute law, all navigable waters belong to the public. (See *navigable waterways.*)

Parcel-based information: information that describes individual ownership parcels; attributes of ownership parcels.

Parcel-level information: information that is of sufficient resolution and accuracy to support valid analyses for ownership parcels.

Patent: the title conveyed by the government describing land disposed of by the government (Brown 1986). A grant of some privilege, property, or authority, made by the government or sovereign of a country to one or more individuals. In American law, the instrument by which a state or government grants public lands to an individual (Black 1968).

Police power: the power vested in a state to establish laws and ordinances for regulation and enforcement by its police (Black 1968).

Possibility of reverter: an interest in land whereby ownership passes from the owner of fee simple conditional title to the owner of the possibility of reverter upon failure to meet the condition (SCWRC 1989). This term denotes no estate, but only a possibility to have the estate at a future time (Black 1968).

Profits: the right to take a portion of the products of a piece of property. Profits are treated as easements under the law in that the interest is limited to a particular use or resource (SCWRC 1989).

Public domain: all lands belonging to the Federal government (Brown 1986) and which are subject to sale or other disposal under general laws, and not reserved or held back for any special governmental or public purpose (Black 1968).

Public lands: unoccupied government lands that are subject to sale or other disposal under general land laws (Brown 1986).

Publicly owned land: land belonging to a governmental body (Brown 1986).

Quiet Title, action to: an action at law to establish the plaintiff's title to land by bringing into court an adverse claimant (Black 1968).

Remainder interests: upon his death, ownership of land passes from the owner of a life estate to the owner of the remainder interest. The remainderman has no right to the use of the land or its resources, but may prevent the life tenant from using the property "in a way that would substantially and permanently reduce the market value of the property" (SCWRC 1989).

Restrictive covenant: a promise to refrain from specified uses of the land or its resources. A covenant is enforceable by the original parties and their assignees (SCWRC 1989).

Servitude: a charge or burden resting upon one estate for the benefit or advantage of another. Servitude has relation to the burden or the estate burdened (Black 1968).

Taxation: the process of taking or imposing a tax. Exacts money or services from individuals, as and for their respective shares of contribution to any public burden (Black 1968).

Taxation, right of: the right to impose and to take taxes.

Tenancy in Common: property interest held by two or more persons with no right of survivorship. Tenancy in common is the most common type of joint ownership. Upon the death of one tenant in common, one share of the property passes to the heirs, while the other shares remain with the tenants in common (SCWRC 1989). (See *joint tenancy*.)

5 PROPERTY BOUNDARIES

Patricia M. Brown

As we have said, the record of land interests consists of descriptions of their nature and extent. *Property descriptions,* also called *land boundary descriptions, land descriptions,* and *legal descriptions,* record the spatial extent of certain common types of land interests, such as fee simple, easements, and rights-of-way, and primarily in two dimensions. Developing an MPLIS provides the opportunity, and the challenge, to create a spatially accurate compilation of property descriptions in the public record. Unfortunately, this is not a straightforward task. Typically, the property descriptions for any particular area contain contradictions, inconsistencies, errors, and omissions. At present it is up to the owners and the courts to resolve these problems based on the evidence. The system that has evolved to guarantee security of interest (described in Chapter 4) is a response to the difficulty, delay, and cost associated with this means of resolution.

The compilation of property boundaries brings to light inconsistencies in the evidence. Methods and accuracies for compiling land parcel maps, some of which are presented later in the *Guidebook* are the subject of considerable discussion in the field of geographic and land information systems at this time because they significantly affect the cost and utility of an MPLIS. They also determine the system's contribution to improved land records. The underlying issues are found in how property boundaries are described and monumented, which are the subjects of this chapter and Chapter 6.

PROPERTY DESCRIPTIONS

For any particular parcel, the chain of title leads back through a series of property descriptions to the original conveyance. If it does not conflict with the descriptions of neighboring parcels, the original description sets the boundaries of

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all subsequent divisions of the land. These in turn bound later divisions unless parcels are formally combined, as through a subdivision, for example. In addition to the basic division of the land, there may be legal descriptions for easements, rights-of-way (ROW), land use restrictions, and other public and private land interests associated with a particular parcel. Also, a deed may contain a general description, but refer to a plat or another description, i.e., *a description by reference.* Or it may name a lot shown on a plat and exclude a portion by reference to another deed. Finally, some government offices, often the assessor, maintain in their files an abbreviation of the description found in the deed. While this is not a recorded description and may not be complete, it may be the most accessible and is often used in place of the descriptions found in the legally recorded document. Similarly, the compiled parcel maps represent a summary of the recorded descriptions and are commonly used in place of the legal record. There are cases where these documents have been submitted as evidence of title in boundary disputes.

A property description consists of the caption, the body, and qualifying clauses. The caption sets the stage for the rest of the description, providing background information including a statement of purpose. If any later part of the description is in conflict with the caption, the caption rules. For example, if a description begins with "land lying within the southwest quarter of section 10," then the document is limited to that quarter section even if the detailed description runs outside of it. The body contains the detailed recital of the property description. It should be clear and complete, naming all the necessary facts without contradiction or ambiguity. The qualifying clauses may exclude certain rights or areas or include additional rights or areas. Occasionally, a conclusion will be added, containing less important information.

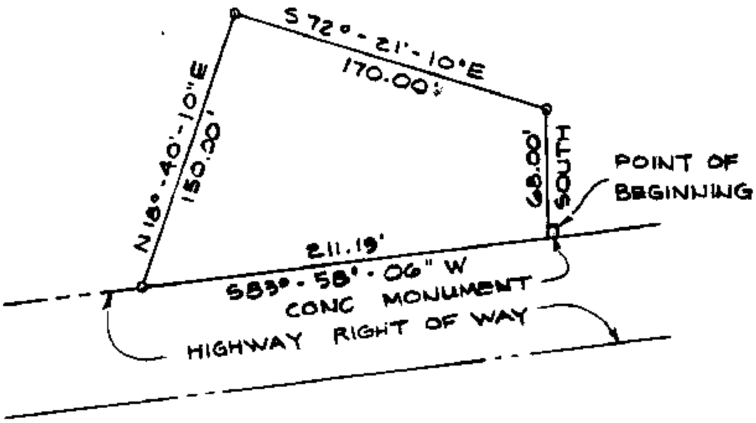
A good property description unambiguously identifies the location of the parcel on the ground and describes the boundaries accurately, briefly, clearly, and completely (McEntyre 1985, p. 29). Most descriptions in the United States use one or more of the following three methods of describing property boundaries: *metes and bounds, the Public Land Survey System* and *aliquot parts,* and *platting* (McEntyre 1985, p. 25). Rights-of-way and easements often use a *strip description.* Other methods include so-called *"of" descriptions* and *coordinates.*

METES AND BOUNDS SURVEYS

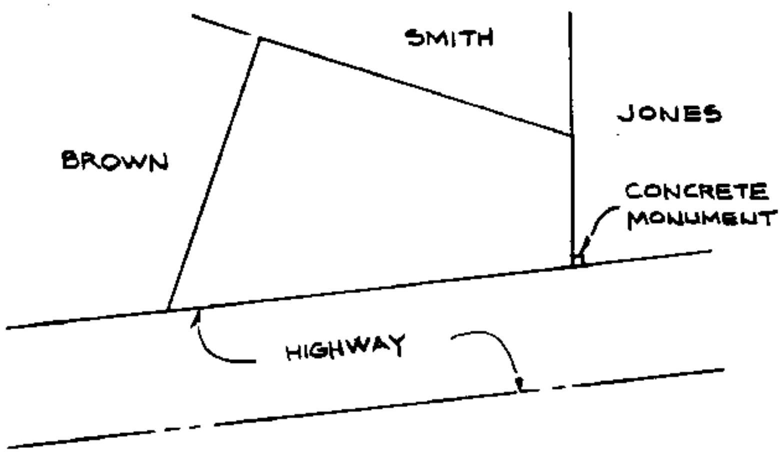
In 18 eastern states, Texas, and Hawaii, legal descriptions usually use the metes and bounds method. (See Figure 5-1.) Metes and bounds are also used to describe subdivision perimeters and irregular parcels in the PLSS states. Typically, metes and bounds describe a parcel of land as though it were an island standing on its own.

Figure 5-1: PLSS and metes and bounds states.

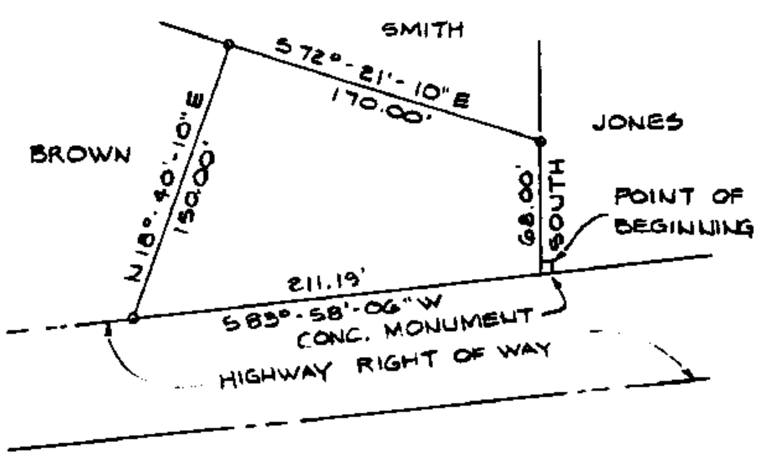
The term *metes and bounds* refers to two kinds of descriptions: *running descriptions* and *bounding descriptions.* Figure 5-2 shows examples of metes and bounds descriptions. In a *running description,* metes, or measures of angles or distance, predominate. The narrator starts at a *point of beginning (POB),* which may or may not be related to other landmarks in its vicinity. The description then runs either



a. **Metes:** Beginning at a concrete monument, thence S83°-58′-06″W 211.19 feet; thence N18°-40′-10″E 150.00 feet; thence S72°-21′-10″E 170.00 feet; thence South 68.00 feet to the point of beginning.



b. **Bounds:** Southwest along the highway, Northeast by land of Brown, Southeast by land of Smith; South by land of Jones to the aforementioned highway.



c. **Metes and bounds:** Beginning at a concrete right of way monument, thence S83°-58′-06″W 211.19 feet along the North right of way of the highway; thence N18°-40′-10″E 150.00 feet along the East line of Brown; thence S72°-21′-10″E 170.00 feet along the South line of Smith; thence South 68.00 feet along the West line of Jones to the point of beginning.

Figure 5-2: Sample metes and bounds.

clockwise or counter-clockwise around the perimeter boundary, using directions (or bearings) and distances. The line is described as running along or "by" an abutter's property or an abutting street. Each line ends at an angle point or corner, sometimes described by a monument, such as a fence corner, stone mound or iron pipe. The description leads back to the point of beginning and usually gives an area in square feet or acres. A *bounding description* reads as if the narrator were standing within the parcel looking outward, describing each boundary as it is observed from the inside by direction such as northerly, southerly, and a distance. Again, abutting names and features may be cited as well as monuments and acreage.

A legal description may consist of a running description, a bounding description, or a combination of the two. A metes and bounds description often includes reference to a survey plat, which may or may not be recorded with the deed. In case of a conflict, the courts have generally held that the metes and bounds description in the deed prevails over the plat. If the description is vague, then the plat is the controlling feature. A metes and bounds land corner may be any monument that is in one or more descriptions.

THE PUBLIC LAND SURVEY SYSTEM

The Public Land Survey System (PLSS) created the original parcel boundaries for most of the land area in 30 states. (See Figure 5-1.) Authorized in 1785, the PLSS divided land into approximately square parcels. The original *patents,* by which land passed from the public domain into non-Federal ownership, were based on the PLSS. Legal descriptions in the PLSS states still refer to the PLSS either by reference to aliquot parts or to the land corners created and placed under the PLSS. The term *aliquot parts* refers to the approximately square subdivisions of the township and section. PLSS land corners are generally monumented at township and section corners and at quarter section corners, when they are present.

The measurements shown on the PLSS plats filed by the original surveyor do not always correspond with resurveys of the actual monuments. The Bureau of Land Management (BLM), the Federal agency responsible for the PLSS, has published procedures that govern the subdivision of aliquot parts and take this problem into account. Ambiguities and conflicts can arise, however, when metes and bounds are used to describe land within the PLSS, as shown in Figure 5-3. The BLM also has established procedures for restoring or reestablishing PLSS corners which have been *lost* or *obliterated.* The PLSS is described in greater detail in Chapter 6.

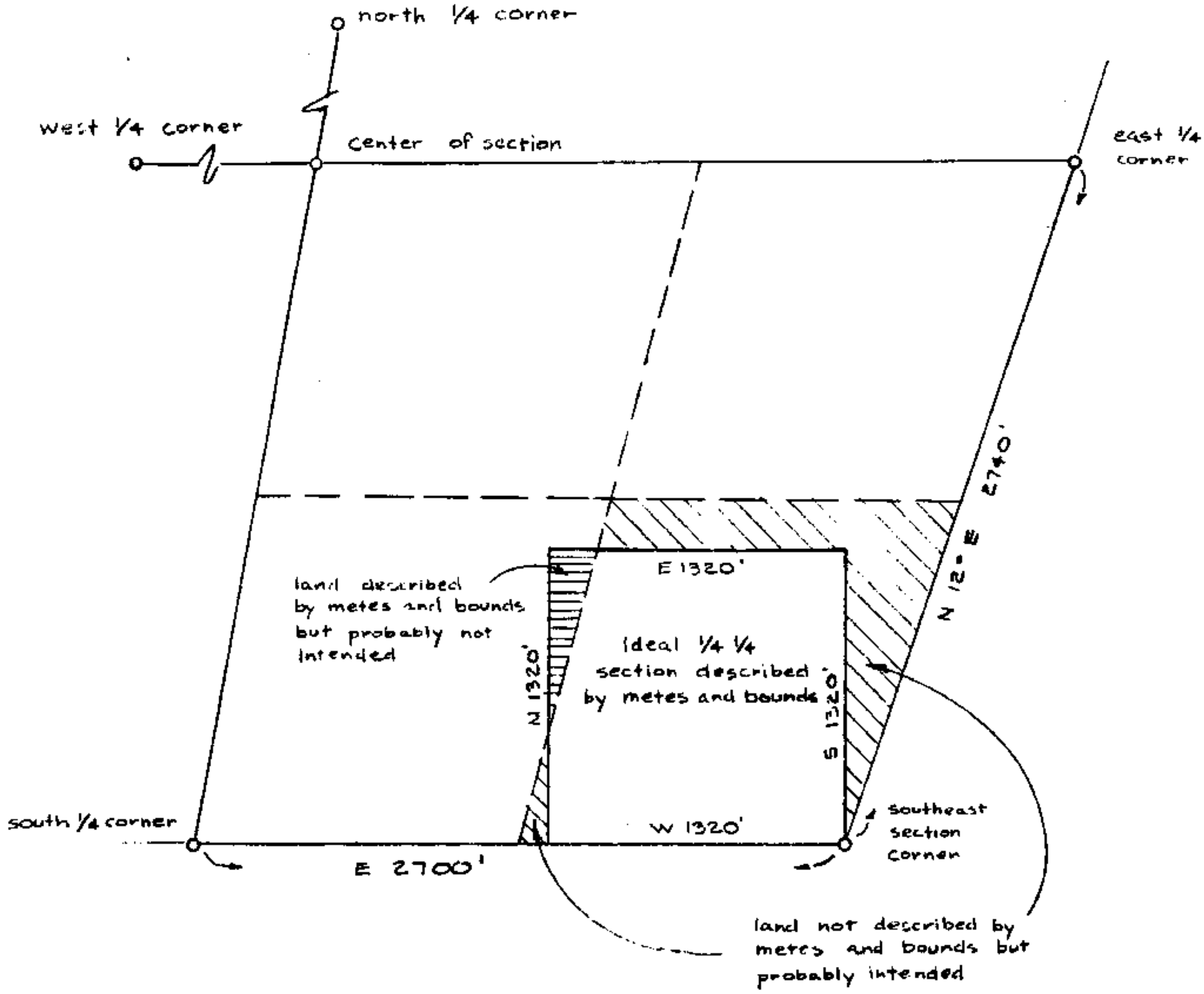


Figure 5-3: Mixing PLSS and metes and bounds descriptions (from Brinker and Minnick 1989, pp. 1071-1072).

PLATTING

The term *plat* is generally used to describe a map or drawing showing property boundaries. The drawings of PLSS surveys are called plats, as are those submitted as part of the subdivision process in most jurisdictions. Most states and many local governments have by now enacted platting laws, often as a part of subdivision regulations. Typically the platting act requires plat surveys to meet certain accuracy and monumentation standards and to be tied to other monuments to establish the relationship between the parcel and its neighbors, as shown in Figure 5-4. The laws usually require the plat to be recorded as well. In developing areas, the boundaries of a large majority of parcels created in the last 30 to 40 years are described on plats governed by these regulations. While subdivision regulations have broader land development objectives, the purpose of the platting act is to improve the quality of land records. Subsequent legal descriptions and references to parcels created by subdivision plat typically refer to lot number, block or part, the subdivision name, the local jurisdiction, and the state.

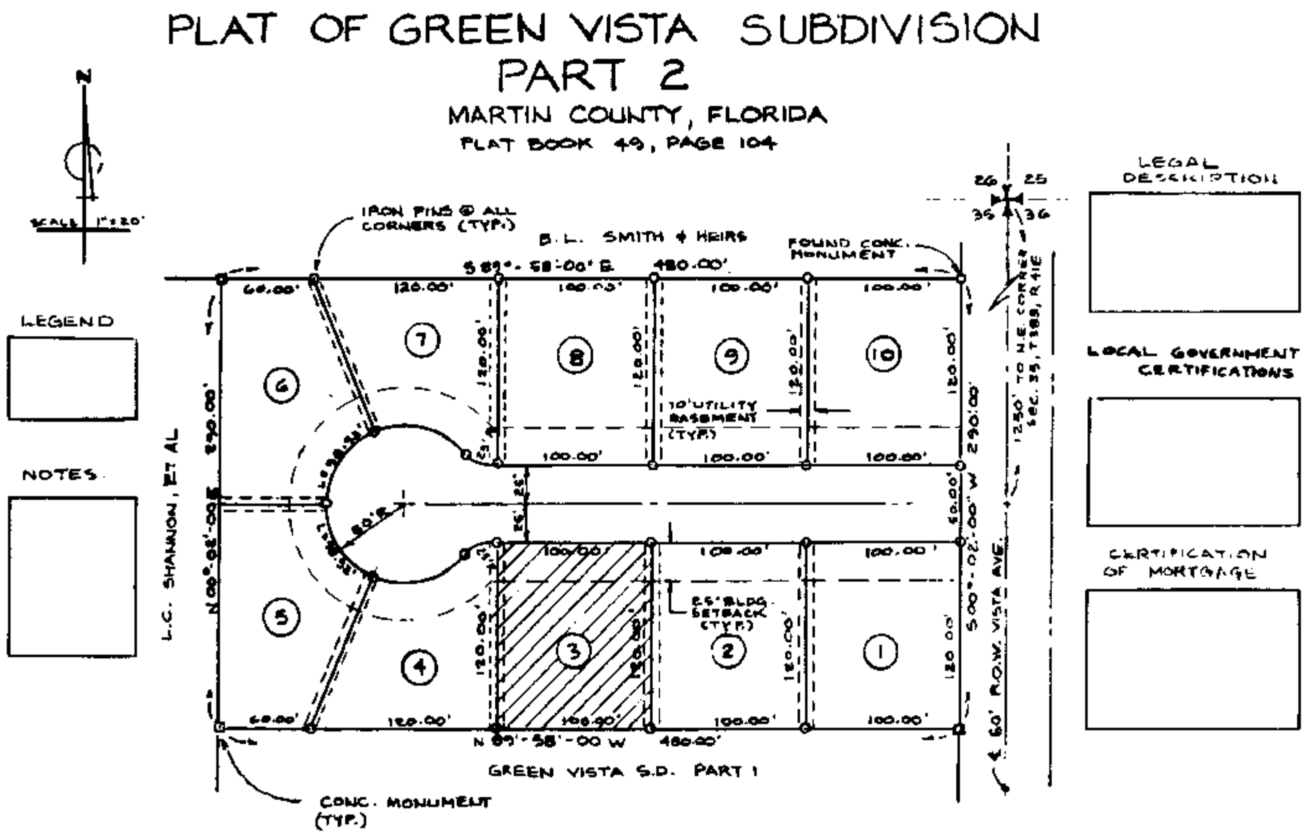
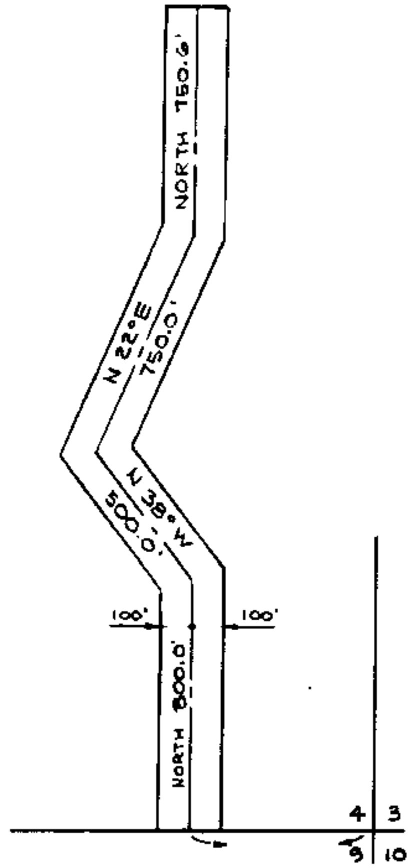


Figure 5-4: A plat.

STRIP DESCRIPTIONS

A *strip description* describes a piece of land by means of a reference line and a width. The reference line is typically a surveyed centerline when the land being described is a right-of-way or easement for travel. For landscape easements, road widenings, and certain other cases, the reference line may be an existing parcel boundary or right-of-way boundary. Figure 5-5 shows an example of a strip description.



A strip of land 200 feet wide, 100 feet on each side of the following described centerline:

Beginning at a point on the South line of section 4, Township 35 North, Range 36 East, being 586.4 feet west of the southeast corner of said section 4; thence North 800.0 feet; thence N38°W-500.00 feet; thence N22°E 750.0 feet; thence North 750.6 feet to the north line of the southeast quarter of said section 4; the side lines of said description being shortened or elongated to meet the property lines of the Grantor.

Figure 5-5: Strip description.

"OF" DESCRIPTIONS

The "of" (or "ly") form of description is often used to specify a portion of an already described parcel, as in "the easterly 35 feet of Lot 12" or "the western half of Section 20." These are useful and often the simplest way of describing the intended portion, but they can easily cause difficulties, particularly when irregular shapes are involved, as shown in Figure 5-6.

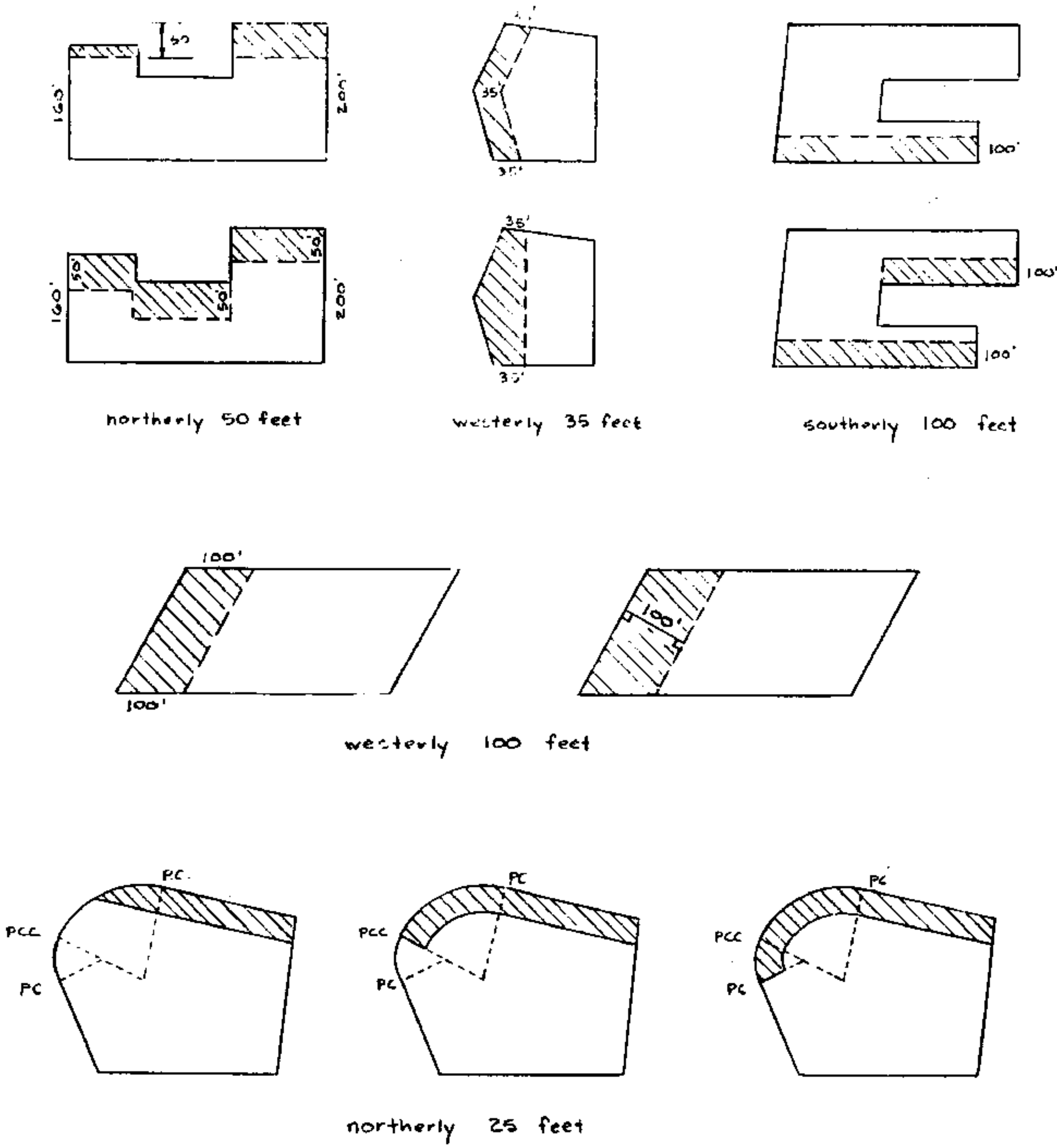


Figure 5-6: Irregular parcels and the "of" description.

GEOGRAPHIC COORDINATES

The use of coordinates such as latitude and longitude or state plane coordinates in property descriptions is still uncommon. Their use in parcel mapping and in describing the general location of monuments is growing quickly.

OTHER METHODS

Many other methods to describe property boundaries can be found in the public record. Some are adequate, many are not. Some are extremely simple, such as "the house owned by Brown in George County." Early grants sometimes referred only to a quantity of land in a general area. Some were longer and more descriptive, but not necessarily more definitive, referring to natural or cultural features that cannot be relocated with assurance. Some included drawings, such as those laying out the first New England towns. These were not necessarily surveyed and monumented, however, and the boundaries on the ground might bear little resemblance to the original plan.

SIMULTANEOUS AND SEQUENTIAL CONVEYANCE

New parcels are created by marking out a portion of an older parcel or of platted land. If two parcels are created at two different times, they are said to be a *sequential conveyance.* As shown in Figure 5-7, the older parcel has *senior rights* over the younger one if the boundaries are found to overlap, that is, the owner of the older parcel has a *superior claim* to the land in dispute. (See Chapter 4.) If there is a gap between the boundaries, it will go to the parent parcel if the second parcel was cut out of the older parcel, or to the state (theoretically) if both were taken out of unpatented land.

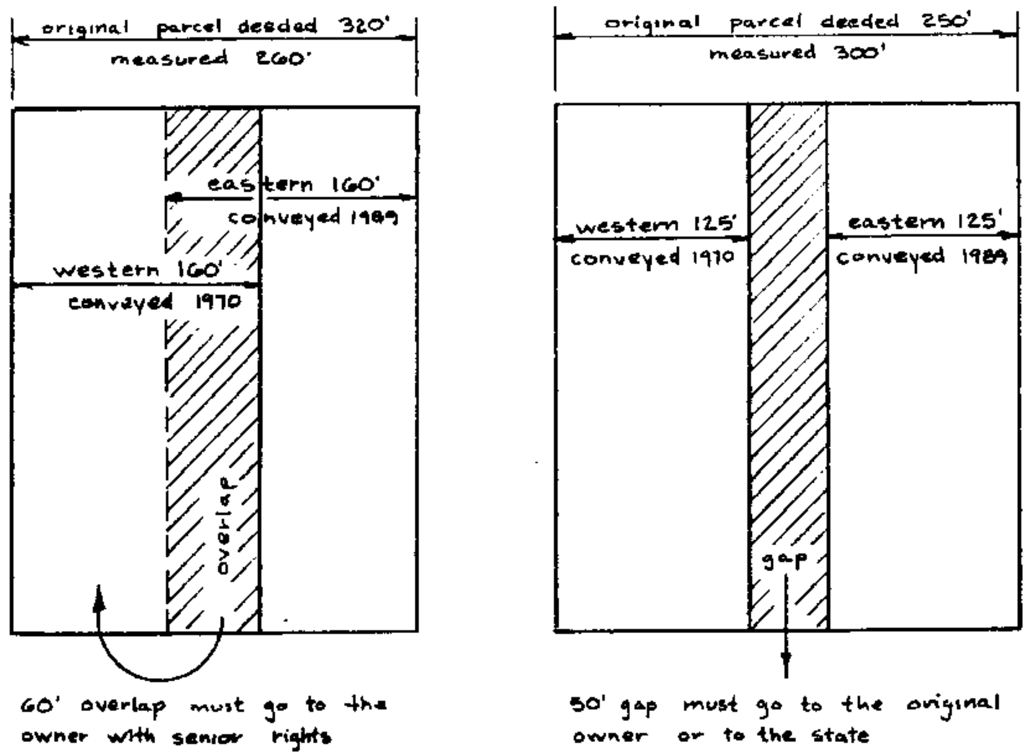
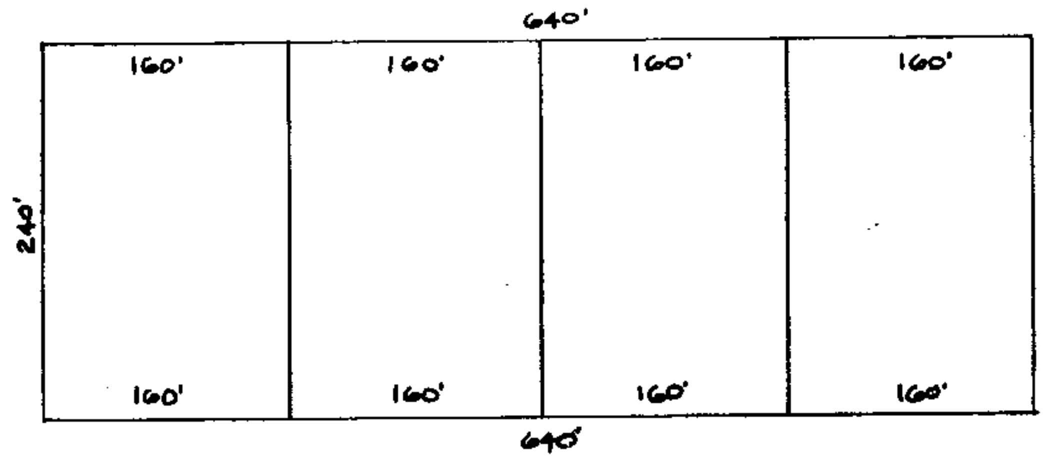
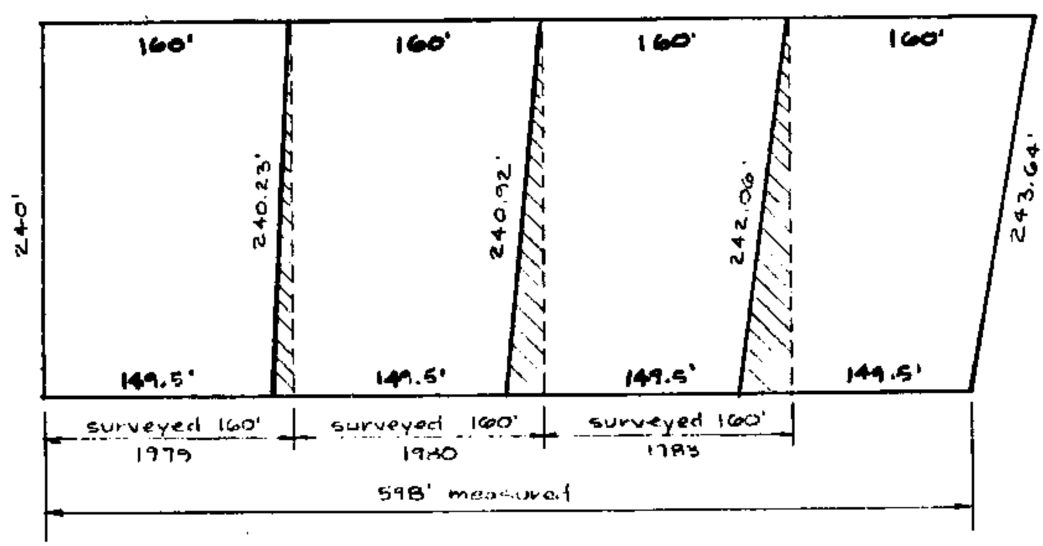


Figure 5-7: Sequential conveyance.

Simultaneous conveyance refers to the conveyance of parcels that were created at the same time, such as those created by a subdivision. Although senior and junior rights might exist between subdivisions, all lots within the subdivision have equivalent rights in the event of gaps or overlaps *even if they were conveyed at different times.* In resolving problems within a simultaneous conveyance, the error is distributed among the lots. Figure 5-8 shows a subdivision 640 feet long by 240 feet deep divided into four lots of equal size. In this example, when each of the three western lots was sold, it was surveyed from the western boundary. When the fourth lot was sold, the total length of the subdivision was found to be 598 feet. Since the lots were created at the same time, the principle of simultaneous conveyance dictates that the error be distributed among the lots. When the actual measurement between land corners differs from the record measurement, new distances are calculated for each lot or part based on the proportion of its recorded dimensions to the recorded distance between corners.



a. Simultaneous conveyance by subdivision plat.



b. The error is distributed along the south line and the sidelines adjusted.

Figure 5-8: Simultaneous conveyance.

EVIDENCE OF PROPERTY BOUNDARIES

Words, measurements, and drawings constitute property descriptions—the written evidence of property boundaries. There are other kinds of evidence, though, some of which carry greater weight when the location of a boundary is in dispute. In general, our legal system gives greater weight to the physical evidence of the boundary, to the historical or commonly understood location of a boundary, and to well-established *occupation* of the land giving correspondingly less weight to measurements, which are presumably taken from the physical markers, or *monuments*. Therefore, a call for a monument will be given the most weight if elements in the legal description are inconsistent. Monuments can be natural (lakes, rock outcrops, trees) or manmade. A *record boundary* is a boundary described elsewhere in the public record, such as on a map or deed. Record boundaries and calls for ties to monuments or record boundaries are next in weight. Distances and bearings follow. Area is given even less weight if it is not given as a specific call. Because physical evidence in the field is more vulnerable to loss and destruction than the recorded measurements, records of measurements and calculations and of the standards and procedures used often become important in finding and reestablishing monuments, but while measurements and calculations can be precise, there is no guarantee that they are either precise or accurate.

FIXED AND MOVABLE BOUNDARIES

In most cases, the boundary of a parcel is fixed in position even if the exact ground location is uncertain. There are exceptions, however, which can cause uncertainty and dispute. Under riparian (water boundary) law, land can be gradually gained and lost by *accretion* and *erosion*. By common law, the land owner "has a right to all accretions that attach to his land" (Brown 1986, p. 247). Land gradually eroded away is lost to the owner. *Avulsion* is the sudden loss or gain of land, as when a stream changes course. The ownership of land does not change as a result of an avulsive event. *Reliction* refers to the increase in land caused by the withdrawal of water, for example when a non-navigable lake dries up. Such land belongs to the owner of the attached land, although various methods may be applied in determining the boundaries.

Many land records call for a stream or river as a boundary. Some are slightly more specific, naming the bank, the channel, or the thread of the stream. These descriptions are not very precise to begin with; uncertainty and the potential for dispute are increased when waterways change their banks and channels.

DISCREPANCIES AMONG PROPERTY BOUNDARIES

Many apparent discrepancies and errors can be uncovered when property descriptions and other land records are compiled onto a single map. These may be rooted in the original grant or patent, or they may have been introduced over the years. They may also be a product of the mapping process and may not exist on the ground.

NATURE OF THE ORIGINAL GRANT

In the United States, the origin of a particular conveyance reaches back through ownership changes, subdivisions, and other episodes to a grant or charter by a sovereign nation, or to a patent from the U. S. Government in the case of PLSS lands. In colonial America, the boundaries of the original conveyance were usually described by metes-and-bounds, such as in the charter from the King of England to The Massachusetts Bay Company in 1628, shown in the box. With original boundaries described like this, it was not uncommon for the same land to be granted to or claimed by more than one party. Some of these cases were brought to court for final disposition based on the evidence presented and the laws in effect; many others persist.

The Charter from the King of England to the Massachusetts Bay Company, 1628:

> All that part of new England in America which lies and extends between a great River ther [sic] commonly called Monomack River, alias Merrimack River and a certain other River ther, called Charles River, being in the Bottom of a certain Bay ther, commonly called Massachusetts, alias Mattachusetts, alias Massatusetts Bay; and also all and singular those lands and hereditaments whatsoever, lying within the Space of Three English miles on the South part of the said River, called Charles River, or of any, or every part thereof; and also all and singular the lands and hereditaments whatsoever, lying and being within the space of three English miles to the southward of the Southern most part of the said Bay, called Massachusetts, alias Mattachusetts, alias Massatusetts Bay; and also all these lands and hereditaments whatsoever, which lie and be within the Space of Three English miles in the Northward of the said River called Monomack, alias Merrimack, or to the Northward of any and every part thereof, and all lands and hereditaments whatsoever, lying with the limits aforesaid, North and South, in latitude and breadth, and in length and longitude, of and within all the Breadth aforesaid, throughout the main lands ther, from the Atlantic and Western Sea and Ocean on the East Part, to the South Sea on the West part.
>
> *(Brown 1981, pp. 155-156)*

The PLSS was designed to solve some of these description problems by specifying standard surveying procedures, by requiring a field survey in advance of settlement, and by making the survey field notes, the plats, and the surveying standards and procedures all part of the public record. Nonetheless, the limitations of equipment, difficult field conditions, economic conditions, and surveying errors resulted in the mislocation of corners. *Once the corner has been placed, however, its true and legal location is its ground position, not* *where records or calculations say it should have been.* Subsequent divisions and conveyances based on record measurements rather than field surveys have resulted in overlaps and gaps between recorded descriptions. (See Figure 5-3.)

The history of original conveyance varies greatly from state to state and even within a state. Knowledge of one locality is not transferred easily to another, and it is important not to assume that what is true in one area is true in another.

HISTORICAL SURVEY PRACTICE AND CUSTOMS

Some of the inconsistency in our land records can be traced back to claims to the same piece of ground, regardless of how it is measured, but many of the overlaps, gaps, and uncertainties result from vagaries and changes in historical survey practice and customs. With relevant U.S. land records originating in Spain, England, France, Holland, and other countries, parcels in the United States are described in a number of linear units including feet, chains, miles, vara, toises, and meters. Areal units include acres and arpents. Further, several variations of any particular unit may have been in use. For example, a geographic mile is longer than an English mile, and a French foot is longer than an English foot. Measures sometimes change, as the Standard Foot did in 1959, and the meter in 1983. Some terms were used whose meanings, though clear at the time, have since changed or gone out of use. In some cases, the unit of measure was approximate since no standard existed, as with the Spanish vara and the French arpent. In Louisiana, the accepted English measure equivalent of the vara differs from parish to parish.

The limitations of equipment have also introduced discrepancies over the years. Most early surveys used the magnetic compass to determine the orientation of a boundary. The magnetic compass measures direction relative to the magnetic pole, which is not the same as the geographic pole. The difference between the two directions is an angle, called *magnetic declination,* which varies depending on location. In the contiguous United States, the magnetic declination ranges between 22 degrees east of north to 24 degrees west of north, 46 degrees altogether. Annual and daily variations also affect measurements taken by magnetic compass, as will magnetic storms and iron-bearing ore near the land's surface. With these variations, and the graduations on the compasses typically used by surveyors, "an angular error equivalent to an error of 1 foot in 300 feet can be expected in many older surveys" (Brown 1986, p. 32). In contrast, subdivision surveys today commonly meet third-order, class II standards of 1 foot in 5,000 feet.

The magnetic compass has been replaced by the transit and theodolite to measure angles. Optical theodolites introduced a magnifying eyepiece to improve visibility of the scales, and the electronic theodolites now available automatically measure the angle. Today's total stations measure both angles and distance. This term is commonly used to describe instruments that read the measurements electronically and store them in computer-readable form. These instruments, which have greatly improved the measurement of angles and distance, are gradually replacing older field instruments.

Early boundary surveys measured distance by pace, chain, rope, or line. Steel tape is a more modern method, and most recently tachymetric and electronic distance measuring (EDM) instruments have been used. Clearly, pacing is an imprecise measurement technique, and chain, rope, and line are subject to stretch and shrinkage with age, temperature, and moisture. Calibration was not rigorous, and a break might be repaired without much care to the effect on the measure. Modern equipment is far less vulnerable to these factors, and precise standards have been established for the foot, meter, and other common measurement units. Survey equipment is routinely calibrated to these standards. Modern surveying instruments are all capable of meeting reasonable standards, making surveying procedures and practice at least as important as equipment to achieving acceptable results.

Customary surveying practices vary across time and space. In some areas it was the custom to throw in 5 percent to allow for variations in chain length. The weight given to survey accuracy varies not only over time but from surveyor to surveyor. Some of the early PLSS surveys are considered quite accurate even by today's standards. Others show very poor practice by any standards. With the PLSS, standards and procedures were standardized and made part of the public record, and today professional surveying standards are published along with the accuracies that can be expected from them. (See Chapter 3, Appendix 3-1.)

MONUMENTS AND RESURVEYS

Surveys to locate property boundaries are conducted for a variety of reasons. The land surveyor collects the relevant documents and attempts to locate the monuments, witnesses, bounds, and other calls in the description. The land surveyor may be asked to perform a *dependent resurvey* or *retrace-*

ment, "following in the footsteps of the original surveyor," following the description and replacing the monuments if they are gone.

The point of beginning for a typical property description is a monumented point such as a PLSS corner. Property descriptions that were never surveyed or monumented and those whose monuments no longer exist rely on less certain evidence for the location of the boundary in the field. A wide variety of monuments are called out in land records. Early surveys in the United States refer to blazed trees, wooden stakes, piles of stones, boulders, land marks, buildings, streams, fences, railroad tracks—whatever was available. The permanence of these monuments varies, and many monuments and their *witness marks* have been lost over time. Some monuments have been replaced through boundary resurveys, but not all resurveys have been conducted by the book or recorded in the public record. Over time, resurveys (both official and unofficial) can result in the placement of monuments for the same point at more than one location. Local surveyors may disagree as to which monument represents the true location. If multiple monuments come into use for a single land corner because of uncertainty about its original location, then subsequent surveys that locate the property will mark off different pieces of land even though the description remains unchanged.

POOR SURVEY PRACTICE

A properly conducted survey of a parcel boundary requires the collection of "all the written, physical, and testimonial elements surrounding" the project (Brinker and Minnick 1987, p. 930). This would include researching all historic deeds and surveys for the parcel in question and adjacent parcels. Unfortunately, clients are often unwilling to pay for extensive research, and may feel that such an in-depth investigation would only cause trouble. This means that parcels may be surveyed many times before a problem is uncovered.

Figure 5-8 shows one example of how poor survey practice can perpetuate an error and make its correction more expensive. Good practice would have the survey of the first, second, and third lots measure the perimeter of the subdivision, as well as measure in to their clients' lots. The surveyor of the first lot would have discovered that the entire length did not match and the apportionment would have been accomplished immediately. If the first few surveyors fail to follow this practice, houses might be in place before the error is finally discovered.

POOR DESCRIPTIONS

Writing a good land description is both an art and a discipline. Unfortunately, the records are full of erroneous and ambiguous descriptions, which are often perpetuated either because the problems are not detected or because changes in the description might slow a transaction, or because the descriptions are prepared by unqualified people who do not understand the importance of a good legal description in correctly identifying and correctly locating a property boundary.

OCCUPATION

Discrepancies can arise between a property description and its corresponding survey and what is occupied. These may take the form of an *encroachment,* when a fence or building corner impinges on the parcel. Or they may be more serious, affecting most or all of a boundary or title. Under certain circumstances, occupation can in fact carry greater weight than written evidence. Therefore, occupation boundaries may be a legitimate description of the extent of a land interest.

SUMMARY

A number of factors have resulted in an accumulation of discrepancies, errors, uncertainties, and inconsistencies in this country's land boundary descriptions. The responsibility for these problems—and for their resolution—does not lie with a single profession, level of government, or agency. Under our system of law, the responsibility for final resolution almost always lies with property owners and the courts. Government agencies and public surveyors have critical roles to play, however, in making information available so that these problems can be discovered and resolved, and in establishing regulations and systems that will lead to the gradual improvement of land records.

Perhaps the most important point for those unfamiliar with land boundary descriptions is that they are not cut-and-dry. The compilation of land boundary descriptions onto a single map often brings many inconsistencies to light. No amount of mapping accuracy or geodetic control will erase years of change, error, and inconsistency. A second important point is that property boundaries are not necessarily simple, uniform, or fixed. A system that records property boundaries must be flexible enough to handle inconsistency, complexity, diversity, and change.

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APPENDIX 5-1
LAND DESCRIPTION TERMINOLOGY

Accretion: increase by external addition; where, from natural causes, land forms by imperceptible degrees upon the bank of a river, stream, lake, or tidewater, either by accumulation of material or recession of water (Brown 1986).

Aliquot parts: refers to the approximately rectangular subdivisions of the township and section.

Avulsion: the sudden loss or gain of land, as when a stream changes course.

Bounding description: reads as if the narrator were standing looking outward, describing each boundary as it is observed from the inside by direction such as northerly, southerly and a distance.

Description by reference: deed may contain description of the parcel's perimeter, but refer to a plat or other description.

Encroachment: when a fence or building corner impinges on the parcel.

Erosion: in riparian law, the washing away of land by a stream or a body of water (NGS 1986, p. 76).

Independent resurvey: runs and marks new lines and monuments regardless of previous surveys.

Land corners: a point on a land boundary at which two or more boundary lines meet. The term is often used to refer to the monument erected to mark the land corner (NGS 1986, p. 49).

Magnetic declination: the angle between the geographic meridian and the local magnetic meridian. Also called *magnetic variation.*

Metes: measures of angles or distance.

Metes and bounds: refers to two kinds of description: *running descriptions* and *bounding descriptions.*

"Of" description: used to specify a portion of an already described parcel, as in "the easterly 35 feet of Lot 12" or "the western half of Section 20."

Patent: the original grant.

Plat: generally used to describe a map or drawing showing property boundaries.

Proportionate measurement: a method of dividing a measured boundary so that each segment bears the same proportion to the whole as the record segment did to the record boundary.

PLSS: Public Land Survey System, the system by which the public domain of most of 30 states was divided into parcels.

Record boundary: a boundary described elsewhere in the public record, such as on a map or deed.

Reliction: refers to the increase in land caused by the withdrawal of water, for example when a non-navigable lake dries up.

Retracement: in a survey it usually means the retracing of an original survey, that is, following the footsteps of the original surveyor (Brown 1986).

Running description: the narrator starts at a *point of beginning (POB)*, which may or may not be related to other landmark features in its vicinity. The description then runs either clockwise or counter-clockwise around the perimeter boundary, using directions (or bearings) and distances. The line is described as running along or "by" an abutter's property or an abutting street. Each line ends at an angle point or corner, sometimes described by a monument, such as a fence corner, stone bound, or iron pipe. The description leads back to the point of beginning and usually gives an area in square feet or acres.

Sequential conveyance: two parcels created at two different times.

Simultaneous conveyance: refers to the conveyance of parcels that were created at the same time, such as those created by a subdivision or by the PLSS.

Strip description: describes a strip of land by describing the location and measurements of a reference line, either directly or by referring to another document, and a width.

Total stations: instruments that read the measurements electronically and store them in computer-readable form.

Witness post (also witness corner): a monument placed at a known distance and direction from a property corner as an aid in the recovery and identification of the survey marker. (NGS 1986, p. 26).

6 THE PUBLIC LAND SURVEY SYSTEM

Gary Speight and Jon Abrams

The Public Land Survey System (PLSS) was created to establish the original property boundaries for most of the land area for 30 states—about 78 percent of the land area of the continental United States. It was the means by which the Federal Government surveyed and disposed of public lands, and has shaped property ownership and land use patterns across most of the country by dividing the land into nominally square sections. The PLSS firmly established three new concepts in land administration:

- the principle of survey before settlement
- the principle of a mathematically designed plan, to be followed throughout the entire area of the public domain
- the creation of a standard land unit of uniform shape and area, with the corners of boundaries physically marked on the ground.

For a vast area of the United States, the PLSS was the original division of land into parcels. An understanding of its history and of the laws and rules that have governed its creation and maintenance are essential to an understanding of land boundaries in this country.

THE EXTENT OF THE PLSS

The terms *public domain* and *public lands* refer to land held by the Federal Government. Lands entered the public domain in several ways: the Colonial states turned land over to the Federal Government; land was acquired by purchase and by conquest; and when a state joined the Union, unappropriated lands often came to the Federal Government as a condition of statehood.

The total area of the 50 states is 2.3 billion acres. At one time or another, the Federal Government has held title to approximately 1.8 billion acres. Today, Federal, civil and defense agencies administer 727 million acres, or 32 percent of the total area. Over the years, some 1.1 billion acres have

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been conveyed to individual citizens, businesses, and non-Federal Government organizations under Federal legal authority, collectively referred to as the *land laws*. The Homestead Laws and grants to individual states to help support public schools, develop transportation systems, and promote economic development account for approximately 50 percent of the land disposed. The PLSS now extends over 1.4 billion acres. Some areas have yet to be surveyed. All of this unsurveyed area is found in 11 western states; 75 percent of it is in Alaska.

PLSS HISTORY

In early America, several types of surveys were performed, using the best surveying instruments of the day, and calling principally on mathematicians, astronomers, and navigators to perform as land surveyors. Most of these earlier surveys were of the metes and bounds type (see Chapter 5), and land parcels were not laid out in a regular pattern.

In the late 1700s, the new government of the United States authorized what would become the most ambitious program of land disposal, ownership recording, and on-the-ground boundary marking ever undertaken. Described as a "marvel of simplicity," the U.S. rectangular survey system was designed to lay out mile square parcels over all of the Federal lands outside of the original thirteen colonies and their western territories.

The Continental Congress authorized the project on May 20, 1785, when it approved the modified recommendations of a committee chaired by Thomas Jefferson. The committee's work was the culmination of much thought, debate, and evolvement of earlier survey activities. Two military engineers, Colonel Henry Bouquet and Thomas Hutchins, were among the original major contributors. (Hutchins later became the first Geographer of the United States.) The 1785 Land Ordinance laid the legal and technical foundation for the country's public land surveys. With Hutchins' personal attention, the first surveys under the ordinance were conducted in Ohio, where the west boundary of Pennsylvania crossed the north shore of the Ohio River. The first township was surveyed by Absalom Martin of New Jersey in 1786. Ohio was the testing ground for the new type of survey, and some changes were made in the law as a result of experience gained in the surveys in that state. By 1805, the rectangular surveys were progressing across Indiana. The system's elements had been well settled by then, and the surveys were eventually extended westward to the Pacific Ocean and Alaska.

The Treasury Department managed the surveys and the public lands until 1812 when, in recognition of the need for an agency that would focus on land management, the Congress created the General Land Office (GLO). Edward Tiffin of Ohio, the first Commissioner of the GLO, made significant contributions to land surveying by consolidating and organizing land and survey records. Later, as Surveyor General, he designed a plan of correction lines to allow the rectangular pattern of surveys to conform to a round Earth.

Until 1910, the public land surveys were usually administered by regional Surveyors General, who contracted with authorized Deputy Surveyors to perform the work. For the most part, the contract system of conducting government surveys had been successful for more than one hundred years. The Civil Appropriations Act of March 4, 1910, ended the contract system of surveys and a corps of government surveyors was appointed. Since then, most Federal cadastral surveys have been performed by Federally employed surveyors.

The Surveyor General often issued a set of instructions to the Deputy to specify the method of survey and the accuracies expected, but, recognizing the need for a consolidation of officially authorized surveying procedures, the *Oregon Manual of Surveying Instructions* was published in 1851. A revision of this manual was published by GLO in 1855 for national use, and later revisions were issued in 1871, 1881, 1890, 1894, 1902, 1930, 1947, and 1973. Subsequent legislation and regulations have added many significant refinements, but the PLSS retains the basic elements set forth in the Land Ordinance of 1785.

DESCRIPTION OF THE PLSS

The PLSS is a rectangular survey system, dividing land into *townships* and *sections*. A regular township is 6 miles on a side, bounded on the north and south by *township lines* and on the east and west by *range lines*. This regular township is further subdivided into 36 sections, each 1 mile on a side. Because the system covers such a large area, adjustments to allow for the curvature of the Earth were needed to allow the system to be locally square. Before each extension of the PLSS, surveyors establish and monument an *initial point*, and determine an accurate latitude and longitude for it. As shown in Figure 6-1, surveyors ran two lines from this point, one north-south and one east-west. The north-south line, called a *principal meridian*, and the east-west line, called a *base line*, act as the reference axis for the rest of the survey. The township lines are intended to be run as true parallels of latitude and the range lines are intended to be true meridians.

As explained in Chapter 2, *meridional lines* (lines of meridian) will converge as they are extended northerly. This convergence is 20 to 50 feet per township in the United States. To compensate for this convergence and to keep townships full size, *standard parallels* are established every 24 miles, that is, every four townships. For a more detailed explanation of the needs for and procedures involved with Standard Parallels, see the *Manual of Surveying Instructions (1973)*.

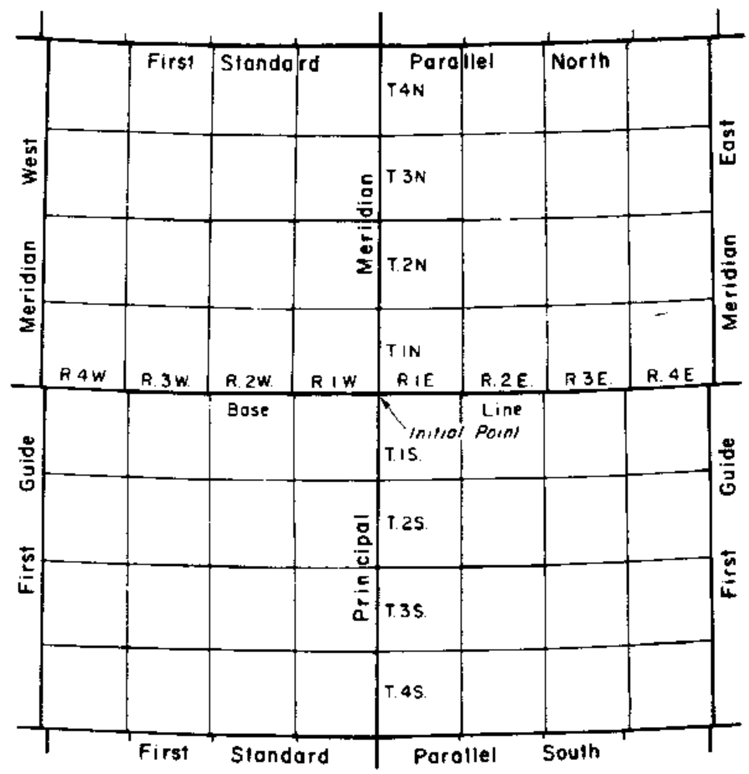


Figure 6-1: Principal meridian and base line (BLM 1973).

Working along the principal meridian and the base line, the surveyor set corners every 1/2 mile and established township corners at 6-mile intervals. Then, the surveyor laid out a 1/2 mile grid, setting monuments at every section corner and quarter corner, as shown in Figure 6-2. Each of the 6-mile squares is a township of 36 square miles, or approximately 23,040 acres. Any specific township can then be located according to its relationship to the appropriate principal meridian and the base line. The township is divided into sections of 1-mile squares containing approximately 640 acres. Individual sections are identified by a numbering system shown in Figure 6-2 starting with section 1 in the northeast corner of the township and ending with section 36 in the southeast corner. The section can be further subdivided into quarter sections of about 160 acres, which became the basic unit under the Homestead Act of 1862. Quarter sections can be divided into half quarter sections of approximately 80 acres and further divided into quarter quarter sections of approximately 40 acres, etc. These subdivisions are called *aliquot parts,* meaning "contained in something else, an exact number of times" (Black 1982, p. 58).

TOWNSHIP LINE

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

RANGE LINE

Figure 6-2: Method of numbering sections (BLM 1973).

Metes and bounds surveys are considered a part of the Public Land Survey System when they are surveyed within any of the public land states and define boundaries of irregular areas of land that do not conform to the legal subdivisions of the PLSS, as shown in Figure 6-3. These surveys may involve prior grants of land, mineral claims, small-holding claims, private land grants, forest-entry claims, national parks and monuments, Indian reservations, lighthouse reservations, trade and manufacturing sites, homestead claims in Alaska, etc. Metes and bounds surveys located upon surveyed land within the PLSS are connected to a regular corner of the rectangular survey. If the location is within an unsurveyed township, a location monument may be set and tied, or the geographic position of the beginning point of the survey may be determined.

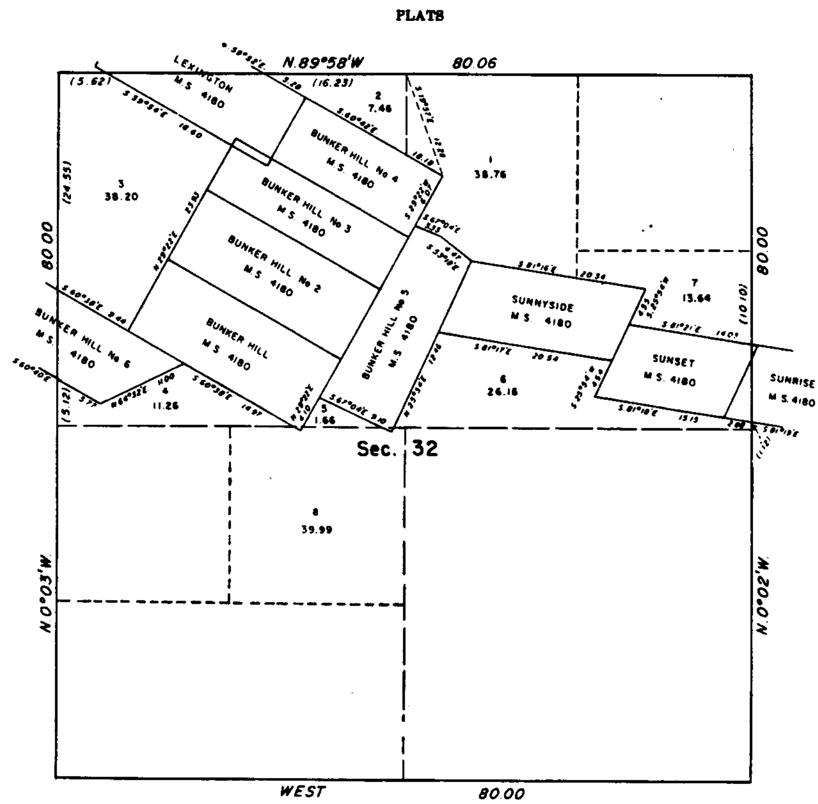


Figure 6-3: Section showing metes and bounds surveys (BLM 1973).

Meander lines are another form of metes and bounds surveys. They are run to segregate a permanent body of water from the public lands. Meander lines roughly define the sinuousities of the banks of rivers or other bodies of water and are used to determine the amount of usable acreage contained in the survey. The instructions regarding which bodies of water should be "meandered" were refined as the PLSS advanced, but in general they specified that navigable waters and waters more than 3 chains across would be meandered. The 1973 Instructions state that meander lines are to be set at mean high-water (Manual of Surveying Instructions 1973, p. 93), but earlier instructions were less specific. Under general land laws, the land under navigable waters is reserved from patent, remaining in public ownership, usually in the hands of the state. While the surveyor was instructed to set meander lines on both sides of navigable rivers, the decision as to whether or not a particular water body is navigable is beyond the surveyor's purview. *"Numerous court decisions in the United States Supreme Court assert the principle that meander lines are not boundaries defining the area of ownership of lands adjacent to water"* (Manual of Surveying Instructions 1973, p. 93). As shown in Figure 6-4, the ownership of land bordering on a meanderable body of water is defined by ordinary or mean high-water of the river or lake, not by the meander line.

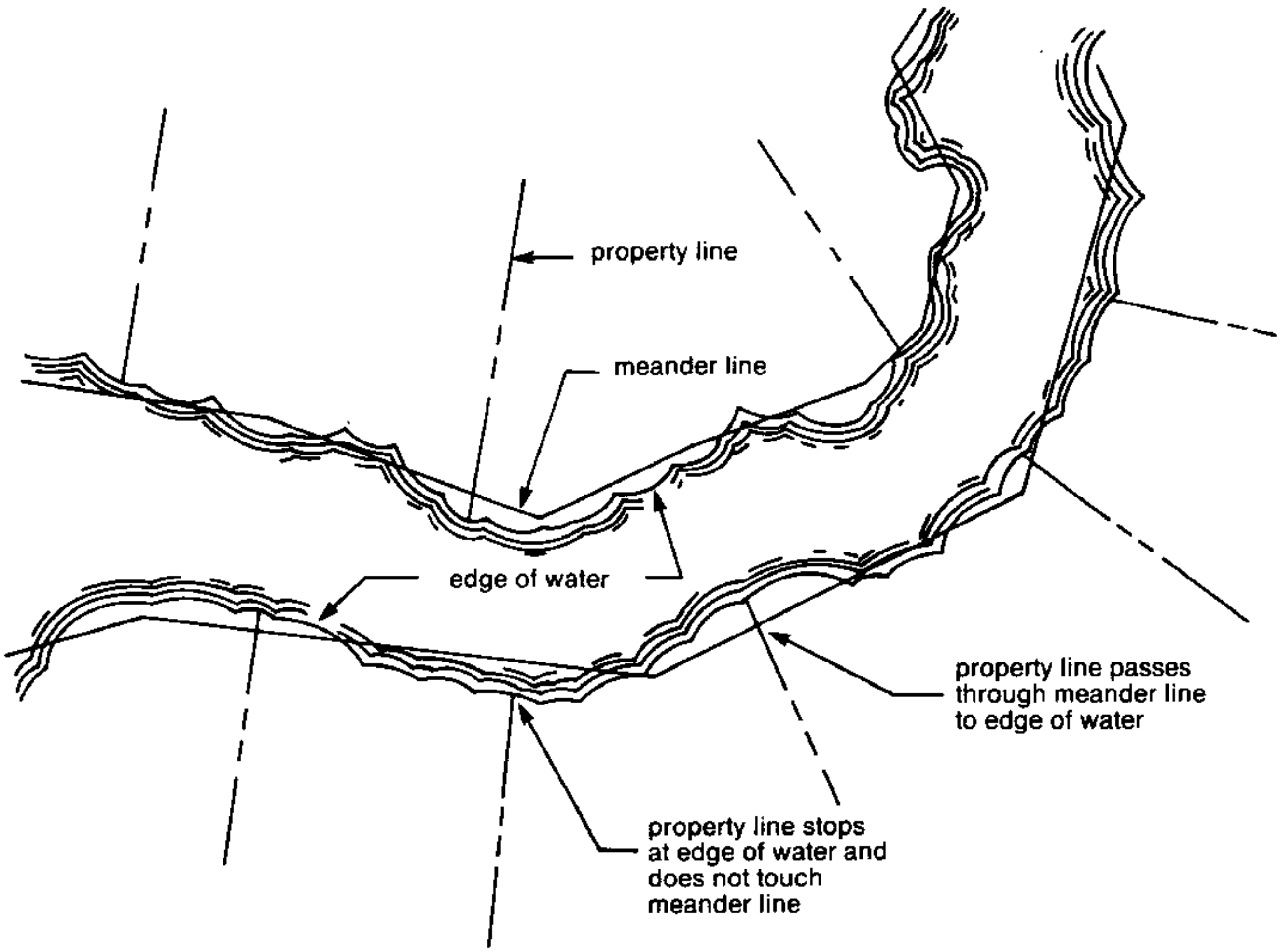
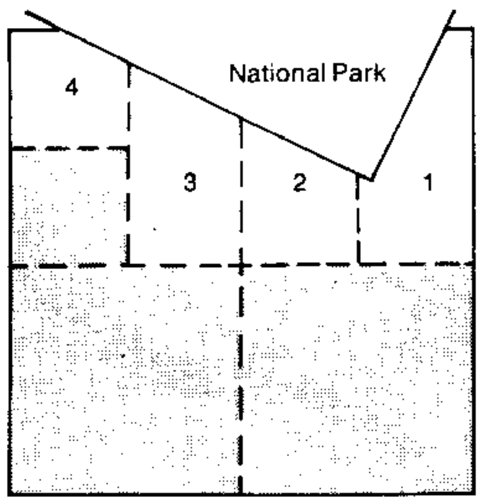


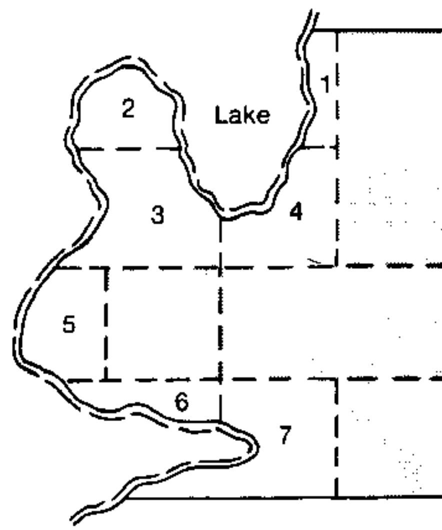
Figure 6-4: Meander lines and ownership.

Under certain circumstances, the subdivision of a township results in irregular parcels of land, which are called *government lots*. The most commonly occurring government lots are those township exteriors along the north and west boundaries of townships. PLSS surveying procedures are such that the effects of convergence and allowable error are pushed to the northern township line and the western range line. In some cases, this resulted in "sections" that were significantly larger or smaller than 640 acres. These areas are subdivided into as many regular aliquot parts as possible down to the quarter quarter section (40 acres) and the remaining parcels are numbered as government lots. (See Figure 6-5.)

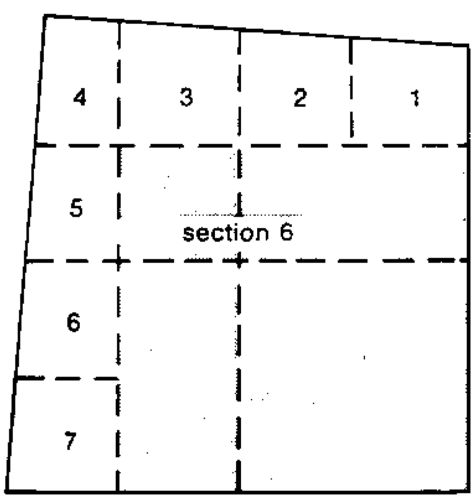
Government lots also occur when meanderable bodies of water or metes and bounds claims intrude on the regular rectangular divisions as shown in Figure 6-5. This kind of township or section is described as *fractional*. It too is subdivided into as many regular aliquot parts as possible down to the quarter quarter section, and the remaining parcels are numbered. Finally, government lots may be created as a result of dependent and independent surveys.



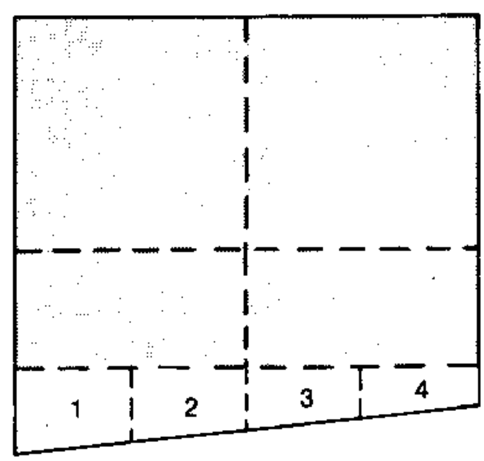
intrusion of metes and bounds



intrusion of navigable water



north and west township boundary condition



misaligned south section line

Figure 6-5: Government lots under the PLSS.

LEGAL DESCRIPTIONS IN THE PLSS

The PLSS makes it very easy to describe uniquely each parcel of land created by the rectangular survey. A township is an area defined by township lines and range lines, which together create a grid, as shown in Figure 6-1. The second row of townships south of the base line is called Township 2 South; the third column of townships west of the principal meridian is called Range 3 West. This township would be called "T. 2 S., R. 3 W." for short. Formal land descriptions include the name of the principal meridian, but most local governments will omit this reference because all of the land in their jurisdiction refers to the same one. If the description refers to one or more sections, these are listed ahead of the township and range: "sec. 14, T. 2 S., R. 3 W."

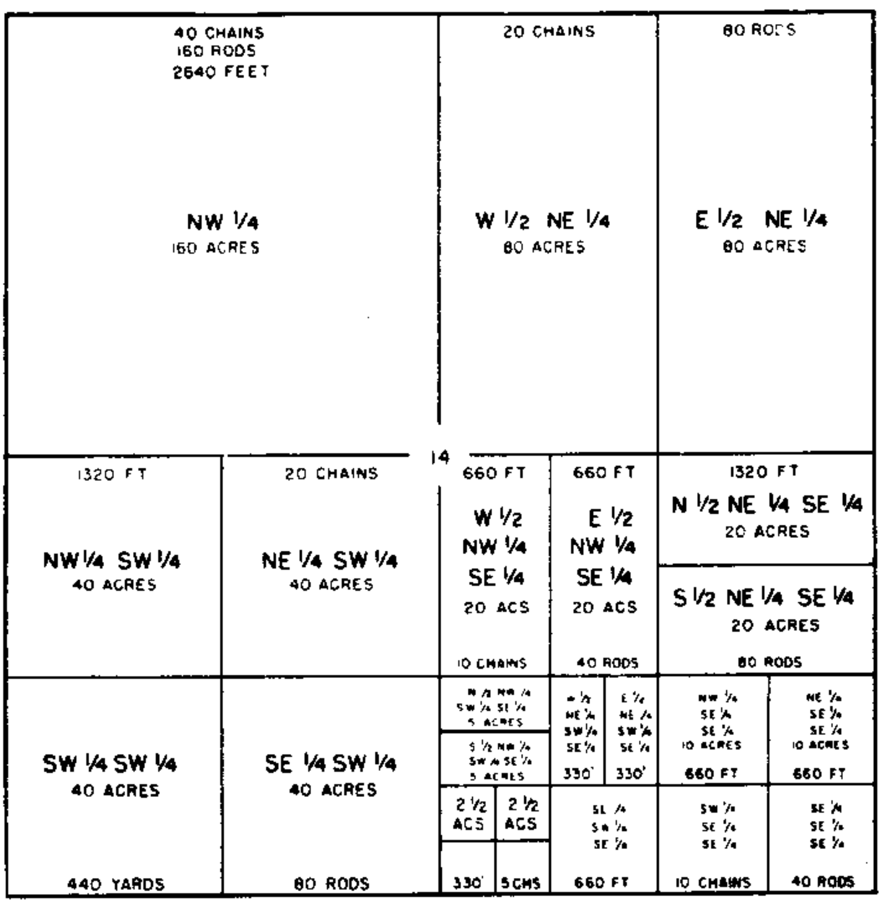


Figure 6-6: Normal division of a section (NRC 1982).

The quarter divisions of a section of land are known as *aliquot parts*. Figure 6-6 shows the normal division of a section into aliquot parts. An aliquot part is always described in relation to the four points of the compass. For instance, a quarter quarter section could be described as the "northeast quarter of the northwest quarter (NE1/4NW1/4) sec. 14, T. 2 W., R. 3 W." and the name of the principal meridian. Contiguous units may be combined. For example, if both NW1/4 sec. 10 and SW1/4 sec. 10 are included, the symbol W1/2 sec. 10 is used. If NE1/4NW1/4 sec. 22 and SE1/4NW1/4 sec. 22 are included, the resulting 80 acre unit can be designated E1/2NW1/4 sec. 22.

Fractional parts are described by substituting the lot number (Lot 7) in place of the aliquot part descriptor. A legal description of such a lot would be Lot 7, Sec. 22, followed by the township, range, and meridian information.

RETRACEMENT SURVEYS AND CORNER RECOVERY

Cadastral surveys, or *land surveys,* create, reestablish, mark, and define boundaries of tracts of land. Unlike surveys that collect information about resources and conditions in the field, "cadastral surveys cannot be ignored, repudiated, altered, or corrected." Other surveys can be redone to collect current information, or to use more accurate methods, but the boundaries created or reestablished by cadastral surveys cannot be changed so long as they control rights vested in the lands affected. The official record of a PLSS survey ordinarily consists of a drawing (a plat or map) and a written description of the field work (field notes). The drawing represents the lines surveyed, showing the direction and length of each such line, and the boundaries, description, and the topography, culture, and improvements within the limits of the survey.

Cadastral surveys under the PLSS fall into two main categories, *original surveys* and *retracement surveys* (or *resurveys).* Original surveys for the PLSS have been completed for the majority of the land in the lower 48 states. Most of the original survey work being done now is in Alaska. Resurveys now present the most challenging and complex projects for the surveyor. These have always been necessary in marking the public lands in order to restore *obliterated* or *lost* original survey lines and monuments. Legally, resurveys must not impair the *bona fide* land rights of affected claimants. Corners established in original cadastral surveys are forever fixed in position even though they may not fall precisely at a stated bearing and distance from a previous point.

The function of the original surveyor has been fulfilled when the survey has been completed and monumented properly, and the official plat and field-composed note record have been approved and filed. The function of the local surveyor begins with the identification of lands which have passed from the government into private ownership based upon the description derived from the original survey. The work may be simple or quite complex, depending largely upon the existence of the original corner monuments or acceptable perpetuations of the corner positions.

In those states where the public land surveys are essentially complete, the so-called *closed states*, the field notes, plats, and other papers relating to those surveys have been transferred to appropriate state offices for safekeeping as public records. The records of 13 states are still held by the *Bureau of Land Management (BLM)* in its state offices. The addresses of these offices in both open and closed states are listed in Appendix 6-1. Survey records in the 20 non-PLSS states are housed in a wide variety of state and local government offices in the respective states.

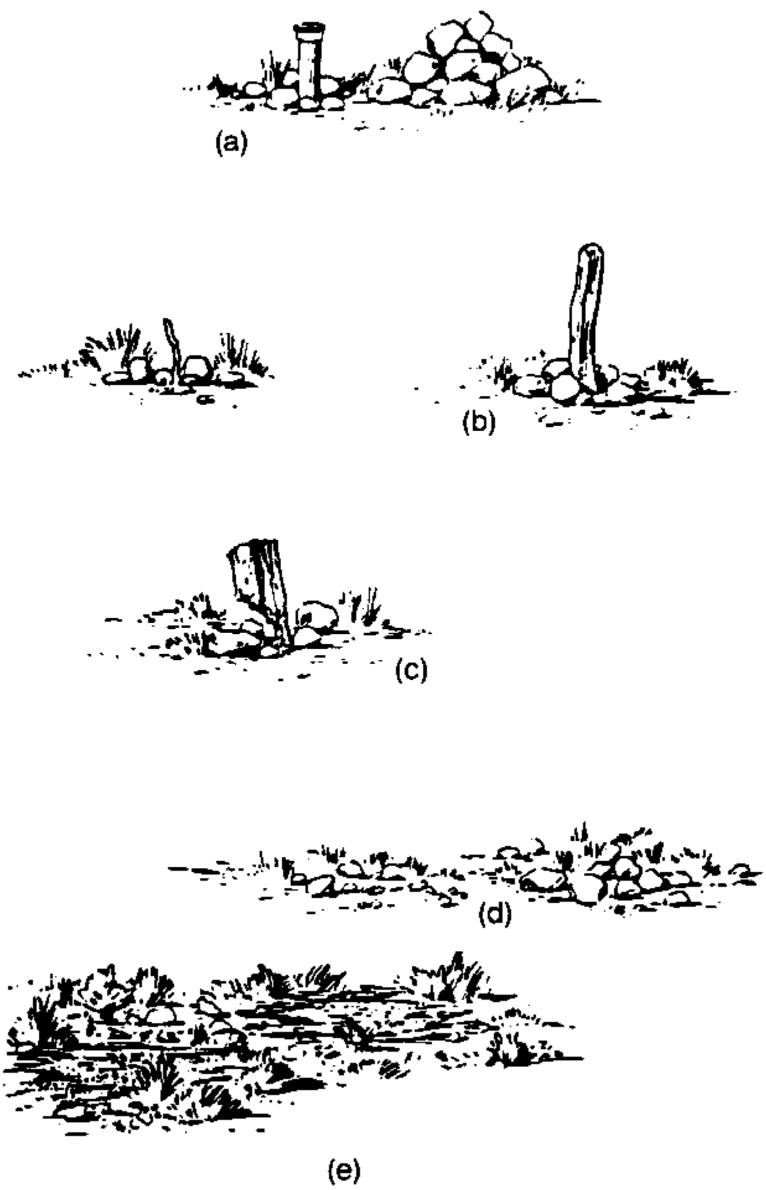
VERIFICATION AND PLACEMENT OF CORNERS

The section and quarter section corners established in the original PLSS survey control the location of the original section lines and create the basic parcel framework in PLSS states. Subsequent subdivisions refer to these original land corners, which should be found, or restored following proper procedures, before any subdivision takes place.

As shown in Figure 6-7, PLSS monuments have taken many forms, including the deposit of some durable memorial, a marked wooden stake or post, a marked stone, an iron post with an inscribed cap, a marked tablet set in solid rock or in a concrete block, a marked tree, and other special types of markers, some of which are more substantial. The original survey usually includes calls to various accessories such as bearing trees, bearing objects, reference monuments, mounds of stone, or pits dug in the sod or soil. Even articles like glassware, stoneware, a marked (X) stone, a charred stake, a quart of charcoal, or pieces of metal have been used as markers. When an old monument is replaced, the old marker is preserved as a memorial.

In many cases, however, the monuments marking the corners have been lost or destroyed, or surveyors disagree as to which monument marks the true location of the corner. The law has established that the original position of the land corner defines the land parcel. When discrepancies occur, evidence of the location of the monument marking the corner is given greater weight than the measurements of angles or distance.

An *obliterated corner* is one whose monument has been destroyed or lost, but whose location can be determined beyond a reasonable doubt from acceptable evidence or testimony. A corner is considered a *lost corner* only when every means has been employed to identify its original position. Lost corners are restored by *proportionate measurement,* in accordance with approved surveying practice and considerations of law and equity. (The rules for the restoration of lost corners have remained substantially the same since 1883.) Proportionate measurement distributes the excess or deficiency in measurement between existing corners in such a manner that the amount given to each interval bears the same proportion to the whole difference as the record length of the



a. Modern post with brass cap and mound of stone

b. Wooden post

c. Wooden post decaying at ground level

d. Corner monument obliterated; remnants of stone mounds identify corner position

e. Corner monument obliterated; evidence of old pits fixes corner position

Figure 6-7: PLSS monuments have taken many forms (BLM 1974).

interval bears to the whole record distance. After applying the proportionate difference, the sum of the parts will equal the measurements of the whole distance.

The process of restoring lost or obliterated corners requires an exhaustive search for relevant documents and field evidence, so maintaining the monuments is generally less expensive than replacing them. The courts may become involved if conflicts arise that cannot be resolved by the parties, generating even higher costs. Unfortunately, the costs are often borne by different segments of society. Maintenance costs generally fall to State and local government (in the closed states), and to the Federal Government's BLM in open states, while legal and surveying costs arising from disputes caused by lost or obliterated monuments are borne by the parties to the dispute, who are often private individuals and companies.

SUMMARY

The Public Land Survey System (PLSS) is the system of rectangular surveys that established the original property boundaries for most of the land area of 30 states. First established by the Land Ordinance of 1785, the PLSS is governed by rules that have been modified over the years. The current procedures are documented in the *Manual of Surveying Instructions, 1973*, published by the Department of the Interior, Bureau of Land Management, the custodian of public lands in the United States.

The PLSS divides land into townships and sections. These can be further subdivided into aliquot parts. Metes and bounds surveys and permanent bodies of water break the rectangular pattern of subdivision. The resulting irregular parcels, as well as aliquot parts that are either larger or smaller than allowed as a result of convergence or error, are called government lots. Retracement surveys and corner recoveries are generally done to reestablish property boundaries. Where corners have been obliterated or lost, an exhaustive search for relevant documents and field evidence is required to assure the bona fide rights of land owners. Retracement surveys of corner monuments can result in bearings and distances that are very different from those shown on the plat and field notes.

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NRC, *see National Research Council.*

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APPENDIX 6-1
REPOSITORIES OF ORIGINAL PLSS RECORDS BY STATE

When the Bureau of Land Management (BLM) has completed the public land survey and turned the records over to the state for management, that state is described as *closed*. In open states, the BLM continues to archive the records. The addresses given below are current as of February 1990.

Alabama:	*closed*	Secretary of State, Montgomery, AL 36104
Alaska:	*open*	701 C Street, Box 13, Anchorage, AK 99513
Arizona:	*open*	3707 N. 7th Street, Phoenix, AZ 85014
Arkansas:	*closed*	Department of State Lands, State Capitol, Little Rock, AR 72201
California:	*open*	Federal Building, 2800 Cottage Way, Sacramento, CA 95825
Colorado:	*open*	2850 Youngfield Street, Lakewood, CO 80215
Florida:	*closed*	Department of Natural Resources, 3900 Commonwealth Boulevard, Tallahassee, FL 32399
Idaho:	*open*	3380 Americana Terrace, Boise, ID 83706
Illinois:	*closed*	Illinois State Archives, Secretary of State, Springfield, IL 62706
Indiana:	*closed*	Archivist, Indiana State Library, 140 North Senate Avenue, Indianapolis, IN 46204
Iowa:	*closed*	Secretary of State, First Floor, Capitol Building, Des Moines, IA 50319
Kansas:	*closed*	Secretary, Historical Society, 120 West 10th, Topeka, KS 66612
Louisiana:	*closed*	Register, State Lands Office, Baton Rouge, LA 70804
Michigan:	*closed*	State Library, Historical Division, 717 W. Allegan Street, Lansing, MI 48918
Minnesota:	*closed*	Secretary of State, 180 State Office Building, St. Paul, MN 55155
Mississippi:	*closed*	Secretary of State, Division of Public Lands, P.O. Box 136, Jackson, MS 39205
Missouri:	*closed*	Department of Natural Resources, Division of Geology and Land Survey Repository, P.O. Box 250, Rolla, MO 65401
Montana:	*open*	222 North 32nd Street, P. O. Box 36800, Billings, MT 59107

Nebraska:	*closed*	State Surveyor, State Capitol Building, 555 North Cotner Boulevard, Lower Level, Lincoln, NE 68505
Nevada:	*open*	850 Harvard Way, P.O. Box 12000, Reno, NV 89520
New Mexico:	*open*	P.O. Box 1449, Santa Fe, NM 87501
North Dakota:	*closed*	State Water Commission, State Office Building, 900 E. Boulevard, Bismarck, ND 58505
Ohio:	*closed*	Ohio Auditor of State Land Office, P.O. Box 1140, Columbus, OH 43266
Oklahoma:	*open*	See New Mexico
Oregon:	*open*	825 Multnomah Street, P.O. Box 2965, Portland, OR 97208
South Dakota:	*closed*	Archives—Cultural Heritage Center, 900 Governors Drive, Pierre, SD 57501
Utah:	*open*	324 South State Street, Salt Lake City, UT 84111
Washington:	*open*	See Oregon
Wisconsin:	*closed*	Public Lands Office, Department of Justice, 110 E. Main St., Madison, WI 53701
Wyoming:	*open*	2515 Warren Ave., Cheyenne, WY 82001

7 WHY IMPLEMENT A MULTIPURPOSE LAND INFORMATION SYSTEM

D. David Moyer

This chapter is designed for use as a stand alone piece for policy makers and others who want an overview of why improvements in local and state government land information systems are needed, and why now is an especially appropriate time to implement such an improvement program.

This *Guidebook* provides considerable information on HOW to improve the land information systems (LIS) in local and state government offices. This chapter provides a summary of WHY. It considers the current status of parcel level land information and technology available. This discussion should be useful to decision makers who are considering modernizing LISs.

FORCES DRIVING IMPROVEMENTS OF LAND INFORMATION SYSTEMS

Two basic forces are driving the current widespread interest in LIS improvements: the *demand* for quicker access to more and better land information at a reasonable cost and the *stream of technology* useful for LIS improvements. This technological stream includes mainframe and personal computers, software, scanners, digitizers, Global Positioning System (GPS) receivers, and more precise geodetic reference frameworks that form the foundation for an MPLIS. Figure 7-1 suggests how these two forces are interacting in society.

Technology flows through the technology gate, depending on a variety of factors including research and development experience and success rates, management attitude, resources, and timely, requested standards. Social demand, on the left side of Figure 7-1, pulls the technology to the left through the social gate. The flow through the social gate is affected by factors ranging from the need for survival to assistance in dealing with increased complexity. Innovations move through

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the social gate when they increase efficiency, meet economic needs, contribute to the common good of society, and are perceived as being lawful.

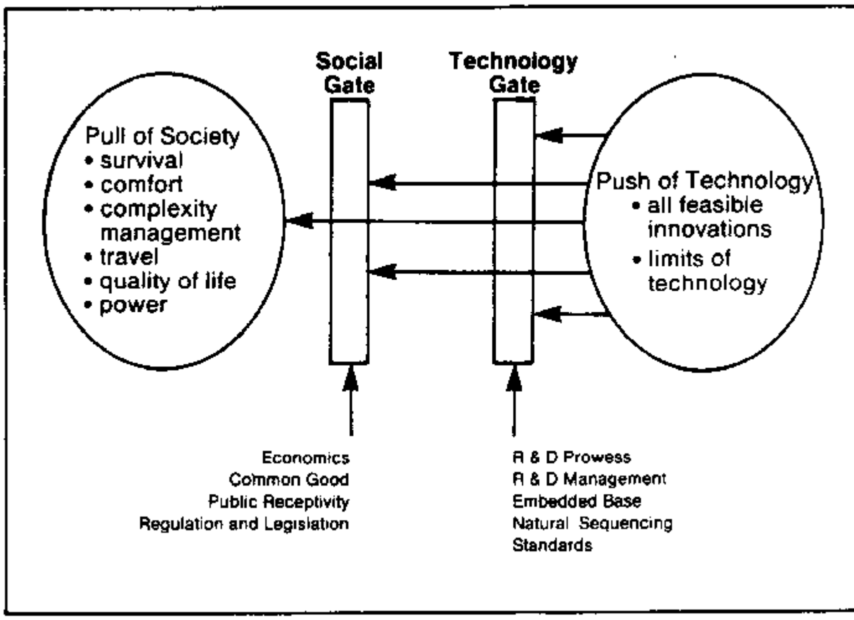


Figure 7-1: The flow of innovations into society (Mayo 1985).

The National Research Council (NRC) statement that there is an "increasing demand for land information at all levels of government" is more relevant now than when written in 1980 (NRC 1980, p. v). The demand for land information arises from the need to make choices about use of the land and its related resources.

The value of information, and thereby the effectiveness of the decision-making process, are directly related to the quality of and capacity of the system that produces the information, as well as the information itself. Current users of land information agree that most current LISs are no longer capable of doing the job and that major improvements are needed very quickly.

WHY CHANGE NOW?

There are many reasons why now is an opportune time for governments to improve their LIS. This section examines the demands that are being made on government for land information and also considers the technology that has recently become available for use as part of LIS. Information systems presently in use can be costly, overly complex, and slow to respond. These systems are unable to respond to many of the emerging problems and policy mandates placed on local and state government. There are additional technological and institutional reasons for making changes now, changes that will increase efficiency and accuracy, reduce costs, and overcome certain constraints to modernization.

AFFORDABLE TECHNOLOGY

Major advances have been made in technologies relevant to LIS. A number of these technologies are now more available and more affordable:

- computer hardware and software
- new survey coordinate reference system
- Global Positioning System (GPS)
- remote sensing
- scanning devices

Data networks, telecommunication systems, and distributed data bases have all emerged as generally available, reliable technologies. Technical expertise is much more readily available—from vendors, consultants, and educational institutions. Data sharing and data access from other agencies is becoming an operational reality. Data such as hydrography, transportation, elevations, and government boundaries from digital line graphs (DLG) from the U.S. Geological Survey, soils from the U.S. Soil Conservation Service, wetlands from state natural resources departments, and Census geography, population, and housing data from the U.S. Bureau of the Census are now all available in digital form. This availability helps reduce the significant cost of database development.

Computer Hardware and Software

Personal computers (PCs) with adequate storage capacity and speed of operation for many land information tasks are now available. Software continues to decline in price and increase in sophistication of problems it can handle. Availability of PC-based systems also makes implementation and training easier, since many personnel in LIS offices are already familiar with PCs.

Application specific software such as 9-1-1 emergency dispatching systems, land use planning, and routing systems are now available. Customized user interfaces make training of personnel on new systems easier and faster. Menu driven systems with a mouse for quick access to icons on the screen help reduce errors, speed results, and reduce operator fatigue.

New Survey Coordinate Reference System

Linking spatial data from different sources depends on a common coordinate system that can be related to all such spatial data. Indeed, the NRC suggested that the national network of geodetic survey monuments is the foundation on which all other parts of the MPLIS must be built. Because the geodetic coordinate reference system for North America had not been revised for over 50 years and tens of thousands of new monuments had been added to the network since the last adjustment in 1927, the National Geodetic Survey recently recomputed the horizontal control portion of the geodetic reference system. Details on geodetic datums and related matters can be found in Chapter 3 of this *Guidebook.*

The new coordinates assigned to the 300,000 horizontal monuments in the National Geodetic Reference System (NGRS) provide an improved, more accurate database. However, some jurisdictions that have a substantial database in place may elect to retain their existing coordinates until less expensive conversion systems become available. The key to minimizing these costs, and to making other aspects of database conversion as efficient as possible, is a carefully developed plan of action, agreed to by both data users and data custodians.

The recomputed geodetic referencing system, known as the North American Datum of 1983 (NAD 83), with its increased accuracy is also most suitable for use with GPS surveying technology. Therefore, jurisdictions considering the use of GPS technology in the near future should strongly consider adoption of NAD 83.

Global Positioning System

Recent advances in land surveying have resulted in improved performance and reduced costs of technologies, which in turn facilitate the adoption of an MPLIS. Until 10 years ago, most land surveyors used traditional instruments such as theodolites and similar ground-based manual systems. However, the implementation of techniques such as Doppler, Inertial, and GPS have cut costs dramatically in many cases. GPS, in particular, has reduced costs and at the same time, improved accuracy. Cost studies in Wisconsin have documented that, compared to manual systems, GPS has reduced time requirements from days to hours and costs from $1,000s to $100s.

An excellent example of the impact of GPS on county LIS modernization is the case of Wyandotte County, Kansas. In 1973, the County Surveyor began a program to build a base map for cadastral mapping that far exceeded the usual accuracy of local mapping efforts. However, to add parcel data to this base map, precise coordinates were needed for each of the Public Land Survey System corners in the county. These coordinates were not available in 1973 and the cost to obtain them was prohibitive, so the Wyandotte County program continued without the coordinate base. However, as a result of the efficiencies and economies of GPS, Wyandotte County has recently put into place a GPS network. This GPS network will now be used as the base for determining coordinate precise positions for each of the PLSS section corners in the county.

Remote Sensing

Various remote sensing techniques—for capturing data from wide geographic areas instantaneously and for monitoring changes in particular geographic areas over a period of time using airplanes and satellites—have been in use for many years. Recent advances in the availability and quality of data captured via satellite have made remote sensing even more cost effective.

Remote sensing techniques, such as photogrammetry, are relatively mature technologies using stereocompilation, analytical aerotriangulation, and orthophoto production. These technologies have continued to become more sophisticated and relatively cheaper.

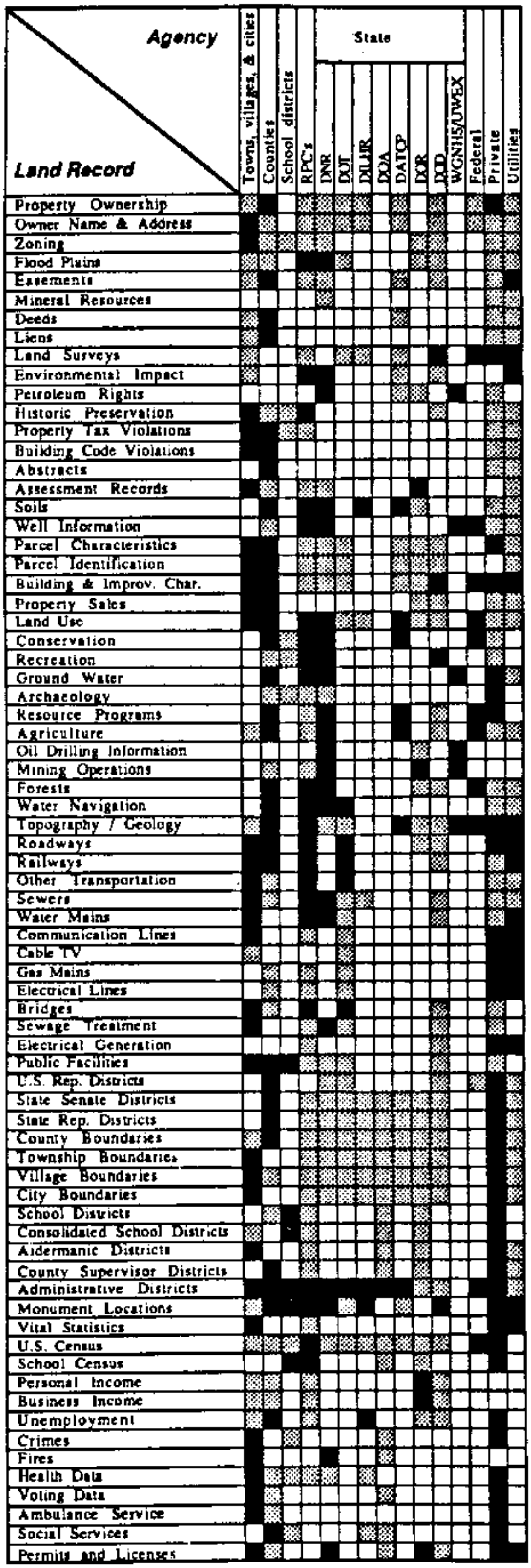
A recent prototype project in Wisconsin included the development of land cover and agricultural land use data for all agricultural lands in a 1200 square-mile area (Dane County, Wisconsin). Historically, these data were obtained by interpreting 35-mm slides collected via aerial photography, requiring considerable time and skill. Satellite imagery from the Landsat program proved to be of satisfactory quality, and meets the needs at an order of magnitude cost savings.

Scanning Devices

The development of a digital database is one of the most important, and most expensive, steps in the development of an MPLIS. Map data capture may be accomplished by use of a digitizing table or with a digital scanner. Scanners capture the map data through a process similar to photography, converting the points, lines, and polygons to digital form with much less human intervention. Evaluation of time requirements for digitizing soils data in Wisconsin found a reduction of two-thirds in the time needed for scanner digitizing, compared to manual digitizing techniques.

INFORMATION DEMANDS

Many demands for information are directed to government agencies every day. Generally information demands fall



Key

■ Collect and use data

▒ Use data collected by others

DNR	Dept. of Natural Resources
DOT	Dept. of Transportation
DILHR	Dept. of Industry, Labor, and Human Relations
DOA	Dept. of Administration
DATCP	Dept. of Agriculture, Trade, and Consumer Protection
DOR	Dept. of Revenue
DOD	Dept. of Development
RPC's	Regional Planning Commissions
GNHS/ UWEX	Geological & Natural History Survey (within University of Wisconsin-Extension)

Figure 7-2: Examples of land information collection and use in Wisconsin.

into several broad categories including: management of facilities and personnel, planning and siting, data acquisition, and service to individual citizens.

Management of Facilities and Personnel

- *Infrastructure Management:* The infrastructure of the United States (roads, bridges, sewers, pipelines, and other utilities) has been seriously neglected over the past three decades. One recent estimate indicates the United States needs to spend $3 trillion dollars to repair our existing infrastructure (Simmons 1990).

New ways of planning for the rebuilding of our infrastructure must be priority based, using several factors including an accurate inventory of the present condition of each segment of each facility, budgets available, safety of citizens and construction workers, usage patterns, and other resource needs and availability. MPLIS is the only efficient and effective way to integrate all of the data necessary and to develop a comprehensive plan.

- *Law Enforcement and Emergency Management:* Managers of police, fire, and other emergency resources face a wide range of geographical problems. Up-to-date statistics are needed for incidences in order to allocate resources to deal most effectively with crime and safety problems. Siting of fire stations to ensure adequate response times requires data on population, types of structures, contents of structures, and traffic patterns at various times of day to construct travel times. These and similar data affect facility siting, personnel allocation, and system design to optimize emergency dispatching and responses to 9-1-1 and 9-1-1 enhanced system demands.
- *Facility Impacts:* Noise and other impacts from airports, freeways, and parks are causes of increasing citizen concern. Means of evaluating noise levels, economic impacts, and social impacts at specific locations, at specific times, with a link to parcel-impacted addresses are needed to separate real problems from frivolous complaints.

Planning and Siting

- *Waste Disposal Siting:* Despite recycling efforts, landfill sites will be needed for the foreseeable future. Detailed information about soils, geology, groundwater and groundwater movement patterns, land use, zoning, and similar matters will become increasingly important, for both locating suitable sites and for monitoring conditions of existing sites.

- *Zoning and Land Use:* Rapid growth and increasing complexity of zoning laws make it increasingly difficult to keep master zoning maps current. The notification of affected land owners of proposed changes is an increasingly costly process. Correct information that can be delivered in a timely manner is essential to avoid political embarrassment, delays, protests, and costly lawsuits.

Competition is increasing among communities for industrial and commercial development. An MPLIS can be used to provide a competitive advantage, by quickly locating acceptable sites, acceptable in terms of existing infrastructure and compatibility with existing plans for the future.

- *Growth Management:* Rapid urbanization in many areas puts continuing pressure on all type of government services. Adequate data are needed to plan, finance, and monitor development, whether for residential, commercial, or industrial use.

Valuation and Voting Districts

- *Property Appraisal:* Continued inflation of property values produces greater revenues and greater citizen concerns about the property tax. This pressure, in turn, presents problems for the value appraisal process. More sophisticated appraisal techniques are available, but they require that more data be collected and maintained, and that these data be more precise than in the past. Photos, aerial photography, and traditional value assessment databases are available in many jurisdictions as free standing resources, but in order to be effectively used, they need to be linked to form a comprehensive database to support the assessment function.
- *Voter Redistricting:* The results of the 1990 Census will be available in 1991. This means that every voter district in the United States must be examined to ensure conformance with current statutory provisions regarding voter representation in Federal, state, and local elections. Data on a wide variety of population characteristics must be linked to additional social and economic data to evaluate and redesign voter districts.

SERVICE TO CITIZENS

Economies in Government

Ways to curtail costs of government—particularly curtailing the extent of duplicate land data—will continue to have major importance. The elimination of duplicate data files, duplicate records, and duplicate map production and compilation reduces costs and increases efficiency. More efficient routing of such services as public buses, school buses, garbage trucks, building inspectors, public health nurses, home bound meal delivery, and maintenance crews is necessary to stretch resources to their maximum. An MPLIS can produce these efficiencies.

Response to Citizen Requests

Citizen participation in the government decision-making process is generally increasing in many areas of the nation. Statutory requirements regarding freedom of information and privacy call for greater discretion and faster response to these information requests. Many local governments are looking for ways to deal more effectively with legitimate requests. Systematic, automated storage and retrieval are necessary for responsive government.

ISSUES IN LIS IMPROVEMENT

The NRC and others have identified several important issues in LIS improvement. These issues include costs—of both the present systems and the MPLIS that will replace them—and demands on LISs—how to assure accessibility, reduce duplication, facilitate aggregation, and ensure confidentiality. Institutional considerations as to how land information is captured, stored, analyzed, and shared are equally important. The importance of parcel-level data, with the opportunities these data provide to help quickly recoup some of the system costs, is also a major concern. Failure to recognize the full impact of these issues is a major factor in explaining the problems of current LISs.

COSTS OF LAND INFORMATION

A 1976 study examined expenditures in Wisconsin to collect and maintain land information at the local, state, and Federal levels of government. A recent update (1986) estimated that this state of 4.8 million people has expenditures of over $135 million per year associated with its land records (WLRC 1987). (See Figure 7-3.) This means that each Wisconsin resident is paying $31 per year for land information—information that is not adequate to meet societal needs as we move toward the 21st Century. (The inadequacy is due not only to the database itself, but also to present capabilities to manage and analyze these data.)

Not only are expenditures for land information large, they are also growing at a rapid rate. A recent study by Automation, Inc., a private market research firm, projected local government and utility expenditures in the United States ranging from $45 to $90 billion between 1986 and the year 2000 for information and systems to manage the nation's infrastructure.

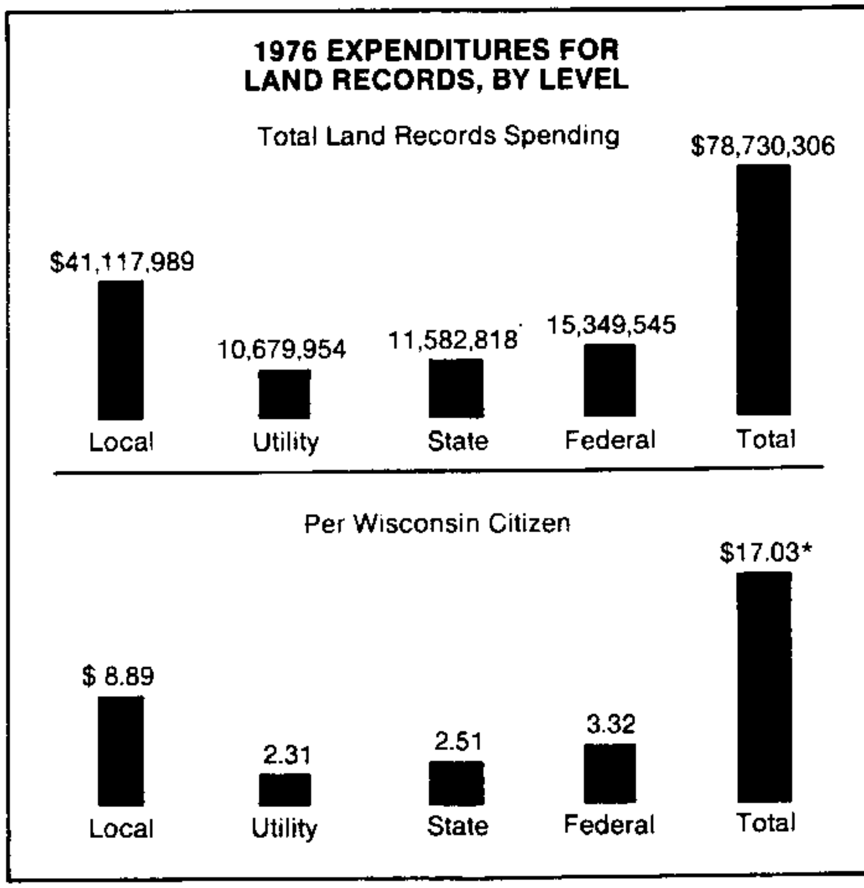


Figure 7-3: 1976 Expenditure for land records in Wisconsin, by level.

Expenditures of this magnitude, coupled with currently available technology, can provide the modern, accurate LIS we need. The large size of these expected expenditures on land information systems technology makes it imperative that the money be spent wisely. If these large sums are not invested wisely during this window of opportunity, it will be extremely difficult to find the resources to make a second attempt. Given the substantial investments that are needed to implement an MPLIS, a multi-year program is probably the best approach for most local and state governments. Finally, an incremental approach to modernization can provide cost savings for the present system through the use of the latest in data collection and management technology—savings that can in turn be used to help finance the next phase of the program.

HANDLING INFORMATION

In 1980, the NRC identified four data handling problems that characterize current LISs: duplication, accessibility, aggregation, and confidentiality (NRC 1980, pp. 21-22).

Duplication

A major factor that contributes to present high costs and conflicting databases in LIS is the duplication of maps, records, and other land data throughout the offices of local government. This duplication is responsible for a major part of the cost implications discussed above.

Duplication occurs when the same, or very similar, land data are collected and/or maintained by two or more government agencies or private companies (NRC 1980, p. 22). For instance, one organization may not be aware of what land data another agency may already have. The time frame in which one office plans to acquire and/or use certain data may be incompatible with the time frame of other organizations that need similar data items. Also, data classification systems among user agencies may not be compatible, leading an agency to infer that it is necessary to duplicate the database.

Even when several agencies start from a common base, each agency may diverge from the base over time. One example is a system based on the common tax parcel base, which over time is divided into separate parcel bases for the assessor, surveyor, zoning administration, and planning officials.

An example of duplication in data collection and storage became apparent in some recent work conducted at the University of Wisconsin. Two sister agencies in the U.S. Department of Agriculture both need data on individual crop fields that are part of each farm unit. Data needed about each field, often on an annual basis, include soil characteristics, the type of crop grown, crop yields, conservation practices planned and in place, and similar data. As a result of a lack of compatibility between the definition of farm "field" used by the two agencies, each collects and maintains its own database on these items. The duplication can be multiplied across more than 3,000 counties in the United States.

Accessibility

The 1980 NRC report identified a number of reasons for the accessibility problem, which they defined as a situation in which a government official or private citizen could not obtain land information. The information may not be available or a search of an unreasonable length may be necessary to locate it. (See Figure 7-4.) The data may be poorly organized with respect to file structure and/or classification scheme, thereby limiting access to data that do exist. Because of these constraints, even public and private users who regularly work with land records in a county may not know the true extent of "public" land information. Too often, many public and private decisions about land are made in ignorance of facts, simply because the information is too difficult or expensive to access.

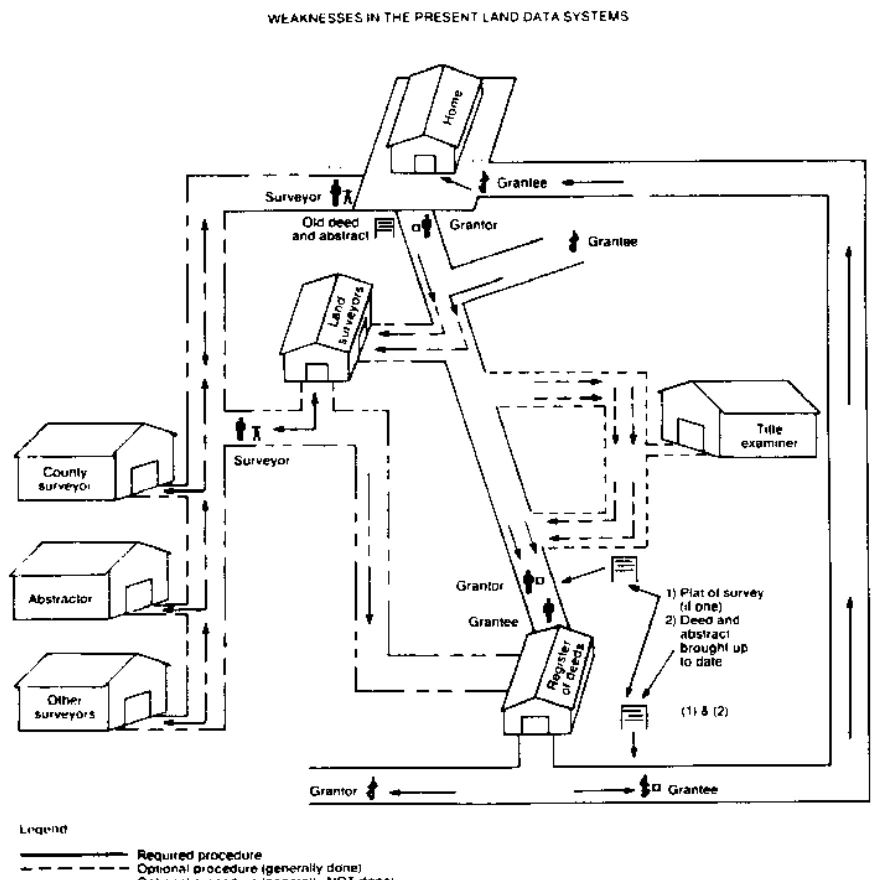


Figure 7-4: The sale of land under the present system (McEntyre 1985).

Limits on accessibility to land information have impact on governments as well as on individual citizens. For example, the State of Wisconsin found it was unable to seek designation as the site of the proposed High Speed Accelerator project because it could not compile and access the wide array of land data necessary. Instead, Wisconsin found it necessary to support the proposal of adjacent Illinois, which had a statewide LIS in place that was capable of linking many separate layers of data and performing the analyses necessary to develop and support a proposed site for the Accelerator.

In 1986, the Wisconsin Department of Transportation conducted a study of the economic impacts and accident rate effects of changing the geometry on highway curves. A full six months was required for one analyst to compile the data needed for the study (on accident rates, highway geometry, and traffic statistics). As part of a feasibility study for an MPLIS, necessary data for the study were collected and compiled in four hours, a savings of 250 to 1. These are the kinds of savings that are necessary if we are to rebuild the infrastructure in this country, and these are the kinds of savings that an MPLIS can provide.

Aggregation

Many information systems currently used in major land management agencies at the state and Federal level are not designed to serve the needs of individual data users, but rather are developed to serve the needs of a particular level or function of government. For example, data at higher levels of government may be so coarse that their usefulness at lower levels is severely limited. Conversely, local data are often so finely disaggregated that use by higher levels of government is similarly restricted.

Data aggregation problems often stem from lack of consistency in standards and quality of data. For example, states find it impossible to combine data from counties to carry out legislatively mandated analyses. Similar examples occur at the Federal level in regard to inconsistent data among the states. Aggregation problems also occur due to the inability to relate parcel level data, such as ownership, to resource polygon data about such items as geology, soils, wetlands, and wastelands (NRC 1983). Inconsistent classification schemes between units of government also make aggregation, analysis, and sharing of data among levels of government difficult or impossible. The inability to share data among departments and divisions within the same unit of government is equally important and common.

Confidentiality

There are two kinds of confidentiality problems. First, access to some land information should legitimately be restricted. Records placed in this restricted category often involve matters of health, finances, or individual employees. Since the system must be able to guarantee the security of such information, the information available from the system must be limited. However, all too often this is interpreted to mean that all information collected by an agency must be restricted, even when there may be compelling reasons to share some of the data with others.

Second, laws and standards defining "freedom of information" and "open records" are too often unclear or contradictory. For example, freedom of information and privacy regulations are often by their very nature in conflict. Also, in the area of land records, the magnitude of relevant legislation or ordinances almost guarantees some conflicts. A study in Wisconsin found over 600 references to land records in the Wisconsin Statutes (Massey 1987). Any conflicts in such legislation invariably lead to disputes that result in delays and restriction on accessibility to information.

INSTITUTIONAL CONSIDERATIONS

The primary barriers to MPLISs are institutional. Most local governments already have single purpose systems that currently contain information on title, taxes, land use, soils, geology, and similar data. What is necessary is a means of connecting these many data files not only to save on data collection and storage, but, more importantly, to make more effective use of this valuable reservoir of data waiting to be tapped. The technology is now available, in the form of LIS, to link the many existing databases to serve the expanding needs of government and industry. To use this technology effectively, we must modify institutional aspects of our offices and work to allow the LIS technology to produce the benefits.

Institutional factors affect land information system operation in at least two ways. First, there is a basic mismatch between how government is typically structured and how land information is collected and managed. Second, there exists a strong resistance to any major changes in both the public and private sectors.

The typical structure of existing governmental organizations is vertical. For instance, in state government, each of several offices is organized around a particular land-related task, such as property assessment, transportation planning, or solid waste management. Each of these offices requires land information, and each is typically part of a hierarchical system that does not relate horizontally to its sister agencies. At the local level, similar examples exist. In the private sector, parallel operations often exist within utility and title insurance companies, which in turn duplicate much local government land information.

In contrast, ownership, zoning, resource, land use, and similar data are most effectively organized on a horizontal layer basis. Building an LIS that is complete, comprehensive, and responsive requires the cooperation of all organizations that are organized vertically, to ensure the horizontal benefits of LIS are fully realized. The importance of the cooperation of governmental units at all levels of government can be seen in Figure 7-5. Through the cooperation of offices at the local, state, and Federal levels, all MPLIS users benefit.

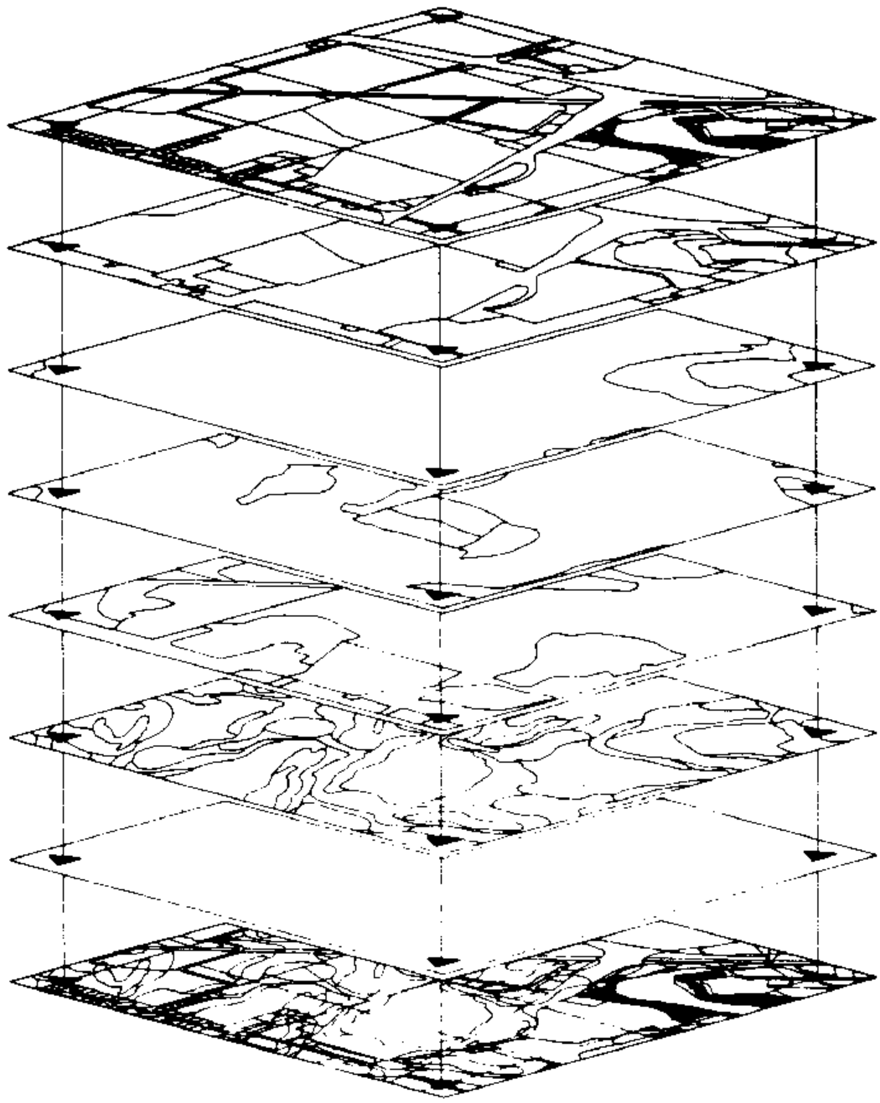
The resistance of many individuals to change contributes to institutional inertia. Overcoming this inertia may require specific legislative changes as well as training programs to assure that everyone knows what changes are being made and why they are being made. To make these institutional changes, we need better integration and standardization of existing activities.

Resistance to change is buttressed by factors such as legislative or administrative requirements for which an agency is responsible. Agencies correctly perceive that they are fulfilling the letter of the law by the use of existing methods. Many see no need to look at the bigger picture. This means that such direction, important if benefits of an MPLIS are to be realized, must come from a higher level (e.g., county executive, county board, governor, or legislature).

PUTTING IT ALL TOGETHER

An MPLIS is not a monolithic information system, but rather an approach that integrates the numerous land information files and offices. The four major structural parts of an MPLIS—parcel level data, the geodetic reference system, base maps, and parcel identifiers to link non-map data to the digital base—are key components to keep in mind. There are also several key institutional aspects of an MPLIS that are critical.

Most of the offices that presently collect and maintain land data will continue to do so. That is, the responsibility of serving as the *custodian* for data files will continue. The improvements under the MPLIS will come as the result of the integration of data from many different files and offices that are presently autonomous "systems." (See Figure 7-6.)



Concept for a Multipurpose Land Information System

Section 22, T8N, R9E, Town of Westport, Dane County, Wisconsin

Data Layers:	**Responsible Agency:**
A. Parcels	Surveyor, Dane County Land Regulation and Records Department.
B. Zoning	Zoning Administrator, Dane County Land Regulation and Records Department.
C. Floodplains	Zoning Administrator, Dane County Land Regulation and Records Department.
D. Wetlands	Wisconsin Department of Natural Resources.
E. Land Cover	Dane County Land Conservation Committee.
F. Soils	United States Department of Agriculture, Soil Conservation Service.
G. Reference Framework	Public Land Survey System corners with geodetic coordinates.
H. Composite Overlay	*Layers integrated as needed, example shows parcels, soils and reference framework.*

Figure 7-5: Concept for a multipurpose land information system.

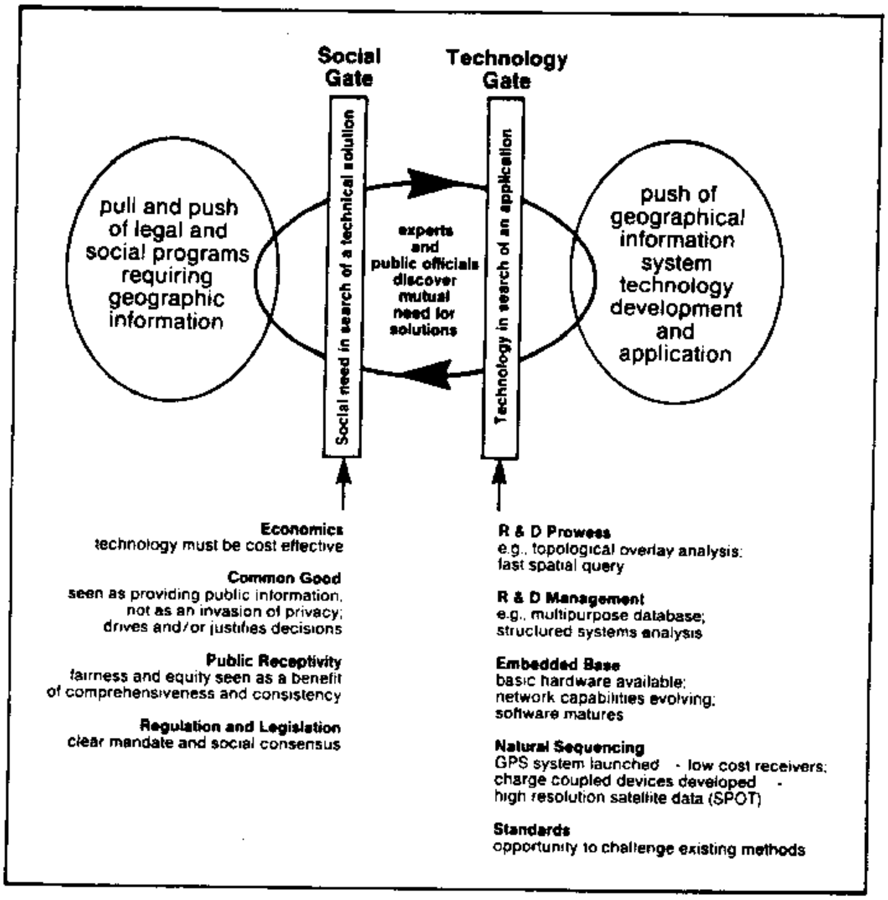


Figure 7-6: The symbiotic relationship between technology and society (Niemann et al. 1988).

The substantial value of investments in an LIS must be protected with a program that assures these databases are maintained. The best way to maintain LIS databases is through the use of on-going functions of government to provide the data for update when transactions occur. For example, changes in ownership, tax assessment, zoning, easements, etc. can all be used to update the database on a daily, weekly, or other periodic basis.

Use of coordinates to bring together disparate data sets is now technically and institutionally possible. Systems in operation in various parts of the United States have demonstrated a number of spatial operators that will have wide application for state and local government. These spatial operators include overlay, proximity, adjacency, and connectivity. Section 5 of this *Guidebook* contains documentation on several of these jurisdictions.

1. Overlay—makes it possible to examine the co-occurrence of information at a particular location or on a particular parcel. Linkage of tax and environmental data, and the linkage of conservation and ownership data are two examples of existing uses in operating systems.
2. Proximity—allows the analysis of areas, for example, of a specified distance from a parcel or polygon boundary. Can be used to determine the impacts of changes in environmental restrictions, as to water, air, etc.
3. Adjacency—facilitates extraction and examination of all parcels or polygons that abut another parcel or polygon. Can be used to notify abutters of zoning hearings or other proposed changes in occupancy or use.
4. Connectivity—permits use of MPLIS data for network analysis. Uses include routing of busses, garbage, and other service vehicles, and the dispatching and routing of emergency vehicles with 9-1-1 and similar systems.

As noted at the outset of this chapter, two major forces are driving the implementation of LIS in governmental units throughout the United States. The availability of technology that enables the use of the spatial operators outlined above is one of the forces that is pushing the technology in Figure 7-6. The second major force is the demand for better, cheaper, more timely information that is coming from users of land information at all levels of government. This demand is also noted in Figure 7-6. Coupled together, these two forces create an interactive process that will continue to drive LIS for the foreseeable future.

The need for improved LISs is increasing at a rapid rate. Traditional, manual land data systems, while they contain much of the data needed, are not organized in a way that permits the retrieval and use of these data in a timely manner.

The availability of state-of-the-art technology makes it possible to implement an MPLIS at an affordable cost. This affordability, coupled with the growing demands on decision-makers who must rely on LISs, makes this a logical time to look toward MPLIS development.

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8 ORGANIZATIONAL CONTEXT

Stephen J. Ventura, William E. Huxhold, Patricia M. Brown, and D. David Moyer

The roots of county government, like many institutions of American government, can be traced to English history, with some significant influences from several European countries (Duncombe 1966). Historical differences help explain the existence of counties in many states, parishes in Louisiana, the dominance of town government in much of New England, and boroughs in Alaska. Many forces have helped shaped these county and other local governments over the years, and new forces, such as automated land information systems, will likely continue to do so into the foreseeable future. The typical local government today is defined by its organizational characteristics, processes, textual records, and graphic records.

ORGANIZATIONAL STRUCTURE

Many local governments have changed relatively little since the individual states were first organized during the first 100+ years of the Union. Many counties grew out of similar organizations in territories that later became states. As in other organizations, a long period of relative stability tends to be self-reinforcing, producing a resistance or hesitancy to change. To further complicate the situation, many county departments and functions are described in considerable detail in state constitutions and statutes. The resulting statutory mandates tend to limit activities of departments and discourage changes.

Outdated organizational structures and procedures incline to foster autonomous departments and hence limit communications

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between personnel. This lack of interaction often produces duplication of effort and, at the same time, hinders discussions across departmental lines that could identify possible overlaps and lead to corrective measures. The net result is a system built to satisfy the mandate of each agency, department, or division. Viewed from outside, the resulting system seems to be the result of "collective irrationality" (Wunderlich and Moyer 1988). These systems, however, are "the outcome of very rational behavior at the individual institutional level" (Niemann 1988, p.43).

This compartmentalized government structure also affects the attitude of the various participants in local government as to changes that might be appropriate. One study revealed that the need to improve the land record system is not a commonly held belief (Niemann 1988, p.46). People who typically use land information for a specific purpose, and for a purpose for which the system was initially developed, are usually satisfied with the land information procedure as it is. To the contrary, other users, who must integrate data from several sources to do their job, exhibit a high level of frustration with how local government collects, stores, and makes available land information. This latter group includes planners, zoning officials, surveyors, and individual property owners.

In essence, local government information systems are the result of, and respond to, mandates. Some of these mandates can be traced to the legislation that established the various offices. Other mandates result from program responsibilities that are added to the work load of government offices from time to time. Environmental, planning, and taxation work have often been the mandates that have led to the development of automated or integrated land information systems over the last 20 years.

MANDATED RESPONSIBILITIES

Mandates in local government offices (as well as state offices) can often be traced to the legislation that established various offices. Other mandates result from program responsibilities added to the work load of government offices from time to time. Most of these mandates are documented in legislation or mission statements of agencies and departments. A recent examination of legislation and mission statements found that in Wisconsin, "agencies at all levels of government had legal mandates to collect, maintain, and disseminate information about various aspects of land" (Ventura 1988, p.1). As is usually the case, these mandates pertained to two primary kinds of data -- graphic (or map) and nongraphic (textual or attribute).

Mandates are often looked at narrowly by both individuals and groups. This "narrowness of scope" view results from many factors, but most importantly results in failure to "examine the potential benefits of cooperation" that could result if a shared data base were in place (Ventura 1988, p.4). The narrowing of scope is often exacerbated by bureaucratic tendency for self-perpetuation. Especially in times of change and for elected officials, the tendency is to support the status quo, rather than risk anything that would alter positions or influence.

Looking specifically at land information, local governments (counties and municipalities) are usually mandated with the responsibility for recording information about land at the most detailed level, i.e., land ownership parcels. Indeed, it is because of this land information responsibility that many see local government as a key factor in the development and operation of a shared land information base in an MPLIS.

With these mandates in mind, it is important to be aware of several perceived characteristics of an MPLIS that affect the organizational context. These are:

- a goal of an MPLIS is to serve a variety of land information mandates at the local and state levels,
- many agencies and departments will share the information in the MPLIS,
- a custodian will be needed for each data file,
- the MPLIS will most likely be developed in an incremental fashion (i.e., over a period of time),
- data in the MPLIS will be of two major types: graphic and nongraphic,
- the system will likely be automated, at least over the long run, and
- coordination must take place on both technical and institutional levels.

PARTICIPANTS IN AN MPLIS

Numerous functions and offices in local government are likely candidates to participate in the development and operation of an MPLIS. For example, both title recording (ownership) and tax assessment (tax parcel) functions maintain and use parcel data. Zoning and planning officials at several levels of government are both providers and users of information about zoning restrictions that apply to use parcels, wetlands, floodplains, and similar areas. Government surveyors, engineers, and public works officials rely on recording of up-to-date surveys, the re-monumentation of survey corners and points, and the accurate ties of these monuments into survey control networks. These prospective participants should certainly be encouraged to be part of any effort to implement an MPLIS.

However, any MPLIS development should also encourage the participation of many other offices, agencies, and individuals in local government. Wide participation is very important since many believe that 75-90% of all data produced and used by local government has a geographic aspect to it. Furthermore, recent market research indicates that LISs are very seldom acquired and developed by a single department (Juhl 1989, p.11). This means that purchases of hardware and software will probably involve several departments. Therefore, the general rule should be to include as broad a group in development and implementation efforts as possible.

ORGANIZATIONAL BARRIERS TO AN MPLIS

MPLIS is often seen as using new technology to solve a particular problem. Technology is only one part of any such solution, for organizational and institutional factors are just as important. In examining reasons for GIS/LIS failure, one commentator has noted that these "systems seldom fail for technical reasons. The technology works; institutions often fail to organize to use it effectively over the long term" (Foley 1988, p.608). It is important, then, to understand the barriers to MPLIS development that exist as a result of current governmental organization. Recognizing these barriers should be helpful in developing a program to move from current manual or semi-automated procedures to an MPLIS, and managing it in such a way as to ensure its long-term success. Potential barriers to watch for include departmentalization, interprofessional barriers, resistance to change, and lack of access to necessary management and design skills.

DEPARTMENTALIZATION

Most local government departments and agencies are established along functional lines. Mandates are often used to establish subgoals for the department, and members of the department become committed to these subgoals and organization-wide goals become secondary (Brown and Friedley, 1988, p.608). Such tendencies often become exaggerated in local government, as functions are assigned to several levels of government and to separate agencies. Some departments and agencies may report to individual elected officials, such as the property appraiser, the county clerk, or the register of deeds. At the same time, most parts of the local government may report to a county administrator, executive, commission, or county board. These varying and sometimes illogical lines of communication and control tend to reinforce the tendency to emphasize division of office goals, and to discourage a broader view that would rely on common goals to drive policy and action.

Sometimes just developing an organizational chart is a useful step toward land records modernization. These charts can show discrepancies between hierarchical organizational and functional relations (e.g., data flow lines). Brown County, Wisconsin, developed such a chart of departments that use land records, and the chart stretched across 12 feet with standard typewriter-sized print! County officials were able to use the chart to more effectively organize departments around functions, instead of existing, traditional lines.

INTERPROFESSIONAL BARRIERS

An MPLIS project brings together a wide variety of professions, a more diverse group than for nearly all other county activities. In some jurisdictions, the development of an MPLIS may involve the knowledge and skills of planners, engineers, surveyors, mappers, computer scientists, conservationists, programmers, lawyers, and financial managers coming from many disciplinary backgrounds. At the outset of an MPLIS project, this group will lack a common technical vocabulary and a common set of values and expectations. Specific efforts will need to be made to overcome these barriers, and to build a common foundation on which to communicate and work.

What are some of the issues that can result in conflict arising from varying needs of professions and difficulties in communication? Spatial accuracy is certainly one area in which differences abound. Land surveyors tend to expect more precise measurements than others, often down to 0.1 or 0.01 of a foot. Engineers may be satisfied with much less accuracy -- up to several feet of tolerance -- and may be willing to acquire greater accuracy, often by re-surveying, only in those specific cases where a project requires it. Planners are more interested in a data base that is fairly complete and that has good relational accuracy (i.e., accurate in terms of the location of one feature with respect to another).

Mappers rely on annotations on their maps to describe its spatial accuracy, and National Map Accuracy Standards (NMAS) are typically used to measure the accuracy of the map itself. (NMAS are based on statistical sampling, a technique which makes some professions nervous, such as those with a broader definition of accuracy, including attribute accuracy and completeness of information).

The management of computer resources on which an MPLIS relies is another area in which conflict might arise. An MPLIS will encompass existing applications such as property appraisal, building permits, and title recordation. These functions may be automated and the computer resources may be managed by two or more data processing groups or departments. The advent of the microcomputer has tended to spread control of hardware across a wider group of managers. In this environment, the integration of hardware, software, communications networks, data, and particularly, standards presents difficult technical and management problems.

The appropriate role for the data processing (DP) department and computer scientists and engineers is another point at which conflicts often arise. Line departments and those headed by a separately elected official often want to develop data processing capabilities within their own department. DP departments prefer that control of all automation remain with their department. At the same time, DP expertise has historically been within single-purpose systems that rely on text-based information. The linkage of text and graphic data in an MPLIS adds substantial complexity to systems that DP departments have often not dealt with before. The need to retrain existing staff and the need to continue to support existing systems and applications present problems for DP departments that cannot be solved overnight. The key is to integrate the expertise of the DP department with the requirements for the MPLIS as identified by user departments, and combine both of these with knowledge about the potential and needs of an MPLIS.

The question of access to data in the MPLIS, vis-a-vis the right to privacy regarding certain files and records of individual citizens on certain items, is another area in which professions differ. The intent of public record laws should be carefully considered when developing an MPLIS. Some states are considering the revision of public records laws, for example, to tie access to a user fee to provide greater flexibility in financing the development of an MPLIS.

RESISTANCE TO CHANGE

Personal inertia is a factor that must be considered in MPLIS planning. Individuals in participating departments may view changes as threatening to their current job, difficult, unnecessary (in their view), or a mistake. They may not see, particularly in the beginning, the benefits that an MPLIS produces. On the other hand, proponents may see many benefits of an MPLIS, but fail to foresee or plan for the many changes in work patterns, individual jobs, and departmental structure that often result.

Careful planning and thorough communication are needed to convey to individuals what they are to do and to help ensure that the new system will actually help completion of tasks for which the staff is currently responsible, as well as new tasks not done before. To overcome resistance to change, the benefits of an MPLIS must be understood by each participant and there must be an open system for communicating the importance of new procedures. If at all possible, the system should provide incentives to participants, supporting them in their day-to-day activities.

Organizations may have inertia to overcome also. There may be resistance to change if there is substantial investment in existing procedures. For example, an organization with several wet-ink cartographers faces the prospect of re-training (or replacing) them and rendering many thousands of dollars of equipment obsolete. There may also be organizational resistance because there is something to hide. The examination of records and procedures prior to automation could reveal years of poorly managed or incomplete data. Again, education and communication are the most effective tools for allaying fears.

MANAGEMENT AND DESIGN SKILLS

Because the MPLIS is a complex system, both technically and organizationally, new management techniques and skills will be required. The use of old techniques and skills in a new, more complex environment may also be required.

Management issues that need to be addressed include:

- What organizational structure is needed?
- How should it be managed?
- How should it be funded?
- How should the cost of the system be shared?
    - and still assure that funds are applied to solutions of user problems
    - and be sure that participant priorities are met.
- How can the transition be managed to minimize disruption?

To be effectively managed, the MPLIS concept and the wide variety of components that make up the system must be thoroughly understood. One of the keys to this understanding is a detailed needs assessment and system design (see Chapter 16).

ORGANIZATIONAL KEYS IN MOVING TOWARD AN MPLIS

A variety of organizational and institutional factors can affect the development and adoption of an MPLIS. Among these are institutional, economic, personal, technical, and personnel factors. These factors played roles in the development of a prototype MPLIS in one Wisconsin county.

INSTITUTIONAL FACTORS

Under the umbrella of broad institutional and organizational factors are a handful of concerns that are particularly applicable. These include management support, steering committees, cost sharing, and system location.

Management Support

Experience from the implementation of information systems in the business community has demonstrated the importance of top-level management support (Ginzberg 1981; Benson 1983). Such support is equally important in government, but even more difficult to obtain, often as a result of frequent changes in leadership in elected offices. Chronic shortage of funds is often perceived by management as a reason (or excuse) not to embark on new programs such as an MPLIS. Still, it is possible to obtain high-level support for MPLIS, and every effort should be made to get such commitments before, or at least early in, the development process.

However, the lack of such support should not be viewed as a fatal flaw in MPLIS development efforts. Experience in Dane County, Wisconsin, provides insight as to how individual departments can work together to build the needed support, even in the absence of initial upper-level management support.

Departments in Dane County developed a cooperative project that relied on informal technical interchanges and cooperative agreements. Individual departments developed budget requests as they needed funds to continue development of their own parts of the MPLIS. These budget initiatives created the main points of interaction between upper level management (i.e., the county executive and the county board of supervisors) and departmental implementors.

Committees to Support MPLIS Development

A mechanism to guide the development and operation of the MPLIS is another important institutional consideration. When efforts are underway, system developers usually find the need for two kinds of committees, or similar groups, to provide the support and guidance needed. One such committee is a steering committee or policy board. Initially, the steering committee might hire a project manager or a consultant to coordinate the activities involved (e.g., deciding what should be in the shared data base, converting existing maps into digital form, developing a data base maintenance and update procedure, and acquiring and putting hardware and software in operation). A second committee that often shares in the oversight function is a technical committee that, as the name suggests, deals with technical aspects of the system, such as hardware and software specifications, data sharing mechanisms, and standards needed for digitizing and other manipulations of the data base.

Most of these issues should be defined in a needs assessment. The nature and development of a needs assessment is fully covered in Chapter 16. As an issue of institutional support, one must recognize that the needs assessment is a critical component of any effort to develop an MPLIS. Guidance of the MPLIS development effort, including the needs assessment, can be handled with either in-house personnel or with outside consultants. There are advantages and disadvantages to each approach.

For example, advantages of using in-house personnel to conduct a needs assessment include using the knowledge base of current employees who are familiar with goals of the agency, what is needed to achieve these goals, and what procedures are currently used in the conduct of agency business. Further, by using in-house personnel, the knowledge gained during the needs assessment will be readily available to the organization.

Use of outside consultants also has a number of advantages. First of all, consultants can bring a fresh approach to a needs assessment. They are generally familiar with effective techniques for doing the assessment and also can approach the task without restrictions fostered by the "we've always done it this way" syndrome. Consultants usually have considerable experience with similar situations (i.e., counties and local agencies) and can often complete the task more quickly and thoroughly than in-house personnel, since consultants can devote full-time to the task. In deciding on which approach to use, complexity of the task and the capabilities and time available of in-house staff will usually lead to the selection of a logical approach.

Cost Sharing

An alternative to acquiring the up-front budgetary support necessary for an MPLIS is to bring together a group of participants, to agree on the scope of the MPLIS, and to develop a mechanism that specifies how the costs of the MPLIS will be shared. Each of these steps is complex and the development of a way to share costs is no exception.

An effective way to develop a cost-sharing program is with the use of a formal memorandum of understanding or a contract. Such an agreement should be developed and approved by all participants. Cost sharing might be based on frequency of use, amount of data required, size of the jurisdiction or agency, or resources available (e.g., tax base or annual revenues of a utility). "In-kind" resources can be considered, but a way to establish their value needs to be clearly established.

System Location

Another important institutional decision is where, within county government, to locate the responsibility for an MPLIS. Placing all of the responsibilities in an existing user department (such as planning or engineering) can lead to inefficient utilization of resources within the organization and also cause problems with which management may not be prepared to deal (e.g., highly technical matters). On the other hand, placing all of the responsibility for the MPLIS in the data processing department can lead to problems as well. DP departments are often not familiar or comfortable in dealing with the unique geographic and cartographic features that are such a large part of the MPLIS. Also, the MPLIS might not be given as high a priority in the DP department as users would like. Such conflicts tend to be frustrating for both users and providers.

Two approaches have been used to successfully overcome the problem of where to locate the MPLIS. One approach is to create a whole new organization to take responsibility for developing the MPLIS project and eventually operating the system. A second approach that has proven successful is to divide the responsibility for the MPLIS: putting hardware and software in the DP department, and responsibility for data in each functional unit assigned the responsibility of maintaining the records for that particular file. This usually provides the best solution to data base maintenance as well, since the department that uses and is most familiar with the data is more likely to keep the data up to date. Whether the MPLIS resides in a separate department or is dispersed among several departments, communication and coordination among the involved parties is critical. Trust in and respect for other cooperating departments is also important.

ECONOMIC FACTORS

Economic factors are often a key in obtaining support for an MPLIS. Management needs to know how much the system will cost, what current costs will be displaced (i.e., what the cost savings will be), and what other benefits can be expected to accrue to the MPLIS. One of the approaches that is usually effective in building the level of management support necessary is to carefully document the costs of the current manual system. When management has been made aware of these usually substantial costs, obtaining approval of the MPLIS costs can be much easier.

Another useful technique is to document the costs of one or more mandates that have recently been imposed on a government or department therein. The likelihood that, based on past history, additional mandates can be expected to continue to add to the work load in the future should also be highlighted for management.

Suggested ways to conduct economic evaluations of MPLIS, both before they are implemented and after they are in operation, are discussed in Chapter 15, which also contains examples of techniques used by specific jurisdictions.

TECHNICAL FACTORS

There are numerous ways that technical factors (both real and perceived) can influence the implementation and use of an MPLIS. While many people believe institutional factors present the most difficult problems for MPLIS development and use, technical factors also present substantial challenges. These factors include the form of existing records (already automated, readily automated, or difficult to automate) (see Chapter 9); the quality, form, and density of existing geodetic control (see Chapter 18); the suitability of existing hardware and software for new or expanded applications; the system design (see Chapter 16); the availability of technical expertise (currently in-house, upgrade of existing staff, or new hires) (see Chapter 14); and the success rate for similar ventures in other departments or jurisdictions (see Appendices).

Sometimes it is possible to acquire help from nearby universities (either free or at a reduced cost) or to obtain assistance from consultants and vendors. The willingness to use such resources often depends not only on the cost, but also on past experience with use of similar assistance.

PERSONAL FACTORS

There are many personal factors that can influence the participation in development of an MPLIS. These factors include level of education, exposure to and experience with computing in general and LIS in particular, and motivation of persons involved (Drury, 1983; Dutton, 1982). These factors were examined in an attempt to explain differences among individuals in three departments that participated in the MPLIS development in Dane County, Wisconsin, discussed previously. All three had similar exposure to computing (none of the departments had automated systems), and the educational levels of the staff in all three departments were comparable (all had at least a bachelor's degree). Staff in one of the departments (Planning) appeared to distrust computing, possibly fearing displacement of their jobs by automation or distrusting the results of computer-based analysis. The most striking difference in Dane County appeared to be motivation of the individuals in various departments. The head of the Land Conservation Department quickly recognized the potential of an MPLIS and became an active promoter, both within his own staff and to other related departments. The Land Records and Regulation Department participated in some experimental work, but only focused on the automation of their manual procedures.

Evidence from other pioneering jurisdictions indicate that early adopters of modern LIS must be willing to take some risks (personal correspondence: Eunice Ayers, Forsyth County, North Carolina, Murray Rhodes, Wyandotte County, Kansas, and Richard Allen, City of Milwaukee, Wisconsin). The importance of a "champion," someone willing to forge ahead in spite of criticism and opposition, is common to the adoption of many new technologies. Until a few innovators have lead the way to show that a new technology is feasible, few others are able to stand up to the critics and continue to seek support until the system is successfully in place.

PERSONNEL FACTORS

In addition to the personal factors are the personnel factors. Two problem areas must be met head-on in any MPLIS effort. One is the need to train or hire the competent staff necessary. Second is the need to keep the quality staff, once it is in place.

Before an MPLIS staff can be put together, a plan is needed as to what positions are required to develop and operate an MPLIS. Below are suggested descriptions for seven staff functions that are essential to an MPLIS staff. When the personnel plan is developed, decisions must be made as to which positions can be filled from within the organization (often supplemented with additional training) and which will require hiring from outside the organization.

Smaller organizations will sometimes be able to combine two or more of these functions in one staff position. Larger organizations may need several staff for the individual functions. The salary ranges are included to provide suggestions as to the relative salary of the various positions. Because salaries in the MPLIS field vary widely by area of the country, local market demand, and other factors, the salary ranges included here should be used with caution.

Careful thought is necessary, not only to assure that the right positions and skills are in place for the MPLIS, but also to assess the impact on the system that various staffing options will produce. For example, hiring from outside could affect the overall acceptance of the system. There might be trade-offs among knowledge about data bases, personalities, and users needs of current staff, versus bringing in new people from outside who will have a fresh perspective.

A good personnel plan is necessary to properly classify staff needed for the MPLIS. This often is difficult, given existing personnel classification schemes and the difficulty in fitting positions such as "GIS manager" or "GIS Analyst" into an existing personnel system. Whereas the changes needed are often difficult to put into place, it is usually worth the effort, since future personnel actions will likely be based on the attributes and skills and career ladders included in the new GIS/LIS personnel structure.

Finally, an on-going training program is needed to keep staff up-to-date, as well as challenged on the job. This is true even if initial hires are made primarily from outside the agency. Training will be needed to keep up with the latest technology (in hardware and software). Also, new uses and users will continue to appear and will need to be included in overall MPLIS activities. Allocation of adequate resources to meet these training needs will go a long way in assuring a successful MPLIS.

Specific MPLIS Personnel Functions

MPLIS Manager

An MPLIS project is complex, involving many different people in a number of different organizations (users, vendors, policy-makers, managers, the press, etc.) It is therefore important for the manager to be a full-time position and for there to be only one manager. This provides a single focus and responsibility.

The MPLIS manager is responsible for three major areas:

- management of the project as it moves from study to implementation,
- management of the system itself once it becomes operational, and
- management of the people involved throughout the entire process.

The manager provides the pivotal point around which all activities of the project revolve. He is responsible for clear, definitive directions and actions during and after implementation. Important qualifications to look for in an MPLIS manager, therefore, include:

- the ability to communicate with people at all levels of the organization,
- a comprehensive understanding of the departments involved in the project, and how the technology involved in MPLIS can be effectively used in them, and
- the likelihood that the person will remain in the position on a long term basis.

Managers with experience are difficult to find, since only a small number of systems have been implemented to date. MPLIS managers often command an annual salary in excess of $50,000.

MPLIS (or GIS) Analyst

The MPLIS analyst's role has similar counterparts in most data processing departments. The analyst must:

- understand the users' world (needs, procedures, missions, and working environments) and

- be able to use technical expertise to apply computer technology in such a way as to improve the users' world.

The analyst studies potential applications, translates the requirements of these applications into technical specifications, and then works with the technical people, vendors, and users to ensure that technical specifications are successfully implemented and used. This position is not necessarily a highly technical one, but the analyst must be able to effectively communicate with users, understand their needs, and prepare clear specifications for technical staff. Therefore, both written and verbal communications are important in this position (technical training on a specific vendor product can be obtained as necessary, often at a later time). Many analysts do have a strong technical background and are able to roll up their sleeves and write computer software code when the job demands it. Analysts currently earn between $30,000 and $50,000, with one to five years experience.

MPLIS System Administrator

The MPLIS system administrator is the captain of the team once the system is installed and operating. While the manager acts as coach, managing the people, planning the work, and dealing with upper level management, the system administrator is responsible for day-to-day operation of the system. The system administrator is responsible if the system or a workstation "goes down," if a file is lost or cannot be accessed, if a new software product must be installed, if a new piece of hardware needs to be added, or if any other problems of system operation arise. This, then, is a highly technical position, requiring a solid computer programming and operating system background. If a network-based system is installed, the system administrator will also need communication experience. System administrator salaries are similar to those for analysts, in the range of $30,000 to $50,000 per year. Because of the rapid rate of change in computer technology, technical expertise is much more important than number of years experience in this role.

MPLIS Data Base Administrator

This person is responsible for the technical design of the data bases that are part of the MPLIS. This position is parallel to those of the system administrator and analyst; the data base administrator is responsible for the data bases that support each application. The data base administrator must ensure that the logical design of each data base is appropriate for the hardware and software of the system. Data base administrator tasks include:

- organization of digital map features into specific layers,
- development of standards and coding structures for nongraphic data,
- establishment of standard symbols and text fonts for maps,
- documentation of data that are stored in the data bases, and
- other data activities (such as data quality control and training on data base management software).

Specific experience with MPLIS is not necessary, but experience in data base administration in other more traditional systems is important. Experience in programming, systems design, and data base management is also an important skill. Salaries for data base administrators are in the range of $25,000 to $40,000, depending on the complexity of the data bases and software.

MPLIS Programmer

Most analysts, system administrators, and data base administrators were programmers at one time in their careers. They may have acquired programming skills through a computer science degree, on-the-job training, or formal training on a specific product by a specific vendor. A programmer is typically adept at using a computer to produce results specified by an analyst, in terms of input, output, and processing specifications. The programmer understands the system software (operating system, communications, data base management, vendor-supplied programs, and general purpose programming languages). The programmer uses the features of this software to produce such things as special purpose programs, specially designed menus, macro-level commands, input screens, and output products. These items are either implemented in the user applications or used to improve the operation of the system.

The work of a programmer is very detailed and requires good concentration and logical skills to analyze problems and processes. Programmers often begin with little programming experience, but usually have a college degree related to a technical field. Salaries in the $25,000 to $35,000 range are common.

MPLIS Processor

This is the least standard job classification discussed here, but can best be thought of as a "super user." The processor often has some programming skills, but his or her main focus is on specific applications, has been fully trained on the system, and can usually implement a simple application without the aid of a programmer or analyst (although regular communication with programmers and analysts is quite common). This position is most effective when located within the user function itself, rather than, for example, in a data processing department. The processor often has been with the organization for some time and therefore understands how it works, but also is very interested in the technology and how it can help other users in the functional unit. The processor will often have a job title related to the function of the unit to which he or she is assigned, but also will act as liaison with the technical support staff of the entire MPLIS project. Depending on skills and training on the system, processors may design user menus, produce ad hoc reports and maps, develop standard operating procedures for specific applications, and even program simple applications. For functional units with high system utilization, this position can either be created as new, or can be converted from other positions that are not needed, once the system becomes operational.

The salary of a processor depends heavily on the salary structure in the functional unit, but generally is comparable to a programmer or analyst (i.e., in the $25,000 to $45,000 range).

MPLIS Digitizer

Digitizers operate work stations that are used for the entry and maintenance of the digital map information. They spend long periods of time at the digitizing table and work station screen, paying careful attention to the map features and their digital representation on the system. Digitizers also often serve as data entry specialists, entering non-graphic data at the keyboard for storage in the data bases. More experienced digitizers also perform edit checks (at the work station or at a backlit table) on data after it is entered into the computer. Drafting skills are useful, but it is more important that digitizers have good knowledge of mapping and drafting products and standards used in the organization. A college degree is generally not required for the digitizing position. Salaries range from $10,000 to $25,000 per year.

Other MPLIS Positions

A number of other positions may be needed in a particular MPLIS installation, depending on the size and complexity of the system and applications implemented. These positions might include:

- cartographers (might be needed to design and produce high quality map products),
- draftsmen (might be required to design highly technical engineering drawings and construction plans), and/or
- photogrammetrists (might be needed to compile and integrate cartographic data from aerial photography onto map manuscripts for digitizing).

SUMMARY

Traditional organization of government, particularly at the county level, presents some significant barriers for implementing MPLIS systems. Other factors, including institutional, economic, technical, personal, and personnel, need to be considered by any entity contemplating the development of an MPLIS. A detailed needs assessment, coupled with a well-thought out plan, can go a long way in overcoming the impediments identified here. Finally, because the roles of LIS and GIS "experts" are new to government offices, implementors need to be familiar with the functions necessary in developing and maintaining an MPLIS. As these new positions become standard in government, personnel offices will need to work hand-in-hand with other departments to ensure the success of an MPLIS in the context of local government.

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9 LAND DATA: TYPES AND REQUIREMENTS

Earl F. Epstein, Patricia M. Brown, and D. David Moyer

INTRODUCTION

Land data can be categorized in a number of ways. However, one of the most important distinctions is between graphic and nongraphic data. While the difference between graphic and nongraphic sometimes becomes blurred, graphic data can be displayed to depict their spatial characteristics and nongraphic data generally apply to the attributes of a spatial object. This chapter examines these two categories of land data, including functions for which data are used, specific kinds of data, form and content of various land records and land record files, compatibility, and data management. The ability to link graphic and nongraphic data is critical to the development of an MPLIS and the usefulness of both types of data. This topic is discussed in Chapter 10 (Linkages). Land records have wide use in both the public and private sectors in the United States. However, in this discussion, attention is focused on local government functions that use and rely on land information. Throughout the chapter, we draw distinctions between graphic and nongraphic data, and explain why the distinction is so important in the MPLIS. This chapter should be useful in the evaluation of existing data and future data needs, a critical step in the design and implementation of an MPLIS.

CURRENT DATA TYPES

NONGRAPHIC DATA

Nongraphic, or textual, data are the dominant type of land data found in the vast majority of local government files today. Nongraphic data include attributes of a parcel, such as value, owner name, area, address, building type(s), and use. These attributes are often derived from other records that summarize field observations or conditions, such as a measurement of spatial area or type of building on the parcel.

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Nongraphic records are words and/or numbers that describe, summarize, or generalize natural phenomena. These phenomena are often continuous and as such, can be represented as graphic (i.e., map) data. However, for efficiency or other reasons, these data may be generalized in the form of a single attribute, such as the dominant land cover type over a parcel. For instance, soils are one data element that can be handled this way, with the soil for a parcel or field coded textually as the one soil type that predominates for that spatial area. Admittedly, the efficiency that is gained in amount of data stored is offset by the loss of detail that exists in the graphic (i.e., a map) of soils that shows the extent of all soil types that are found within a parcel or field.

Nongraphic data can also represent attributes of a particular location. For example, a record may contain an alphanumeric description of a manhole cover, a power or telephone pole, or a street intersection. These records have a spatial character in that they relate to a place, parcel, or coordinate, but they contain much data that is nongraphic. The key for an MPLIS is to make these nongraphic records compatible with graphic records.

The form of nongraphic records is an important factor in their compatibility with graphic (map) records. Nongraphic records come in several forms:

a. *Words, phrases, sentences, and/or paragraphs.* Deeds, documents, court records, and similar records contain a variety of material that may be used directly in the land information system. It may also be referred to by reference or summarized and used in an abbreviated form.

b. *Codes.* Words, phrases, and sentences may be summarized or generalized in terms of a code. Such codes may be assigned as an attribute to a parcel or other land area polygon. Such codes may be derived from planning and zoning maps, soil maps, value assessment records, and similar records. The sources may vary, but each set of codes consists of assigned attributes that are derived from original material and becomes a new set or file in the MPLIS.

c. *Tables of numbers.* Tables can be used as an alternative form of codes. For each parcel or polygon area, or for a spatial location such as a coordinate point, a table of number codes may exist. For example, for a polygon area, a table can be set up to designate a set of utility facilities such as manholes, telephone and power poles, transformers, and substations.

d. *Indexes to record location.* Indexes may be viewed as codes, but they also can be viewed as a separate, particularly important form of nongraphic records. An index indicates the location of other land records that apply to parcels, areas, location, and owners. Examples include tract and grantor/grantee indexes for ownership records and similar indexes for court records and zoning documents.

SOURCES OF NONGRAPHIC DATA

The sources of information that go into an MPLIS are another measure of the scope of the system. As suggested above, a wide variety of information is needed to describe all of the various interests in land and to support the various operational and managerial functions that involve land. Even for nongraphic data, the data exist in a variety of forms. Land data may be in public or private files, in digital format in an automated system or on traditional hardcopy media in a manual system. A couple of examples illustrate the range of data sources that should be considered when designing and building an MPLIS.

Survey data on which to base land boundary files for an MPLIS are particularly dispersed and difficult to compile. The data to build the geodetic reference framework are primarily found in public agencies, although private sources are often an important source as well. (See Chapter 3, "Introduction to Geodetic Reference Frameworks," Appendix 3-2.) Within local government, geodetic data are most likely to be found with the county surveyor or county engineer. Information leading to geodetic data can sometimes be traced through remonumentation of Public Land Survey System (PLSS) section corner projects, as well as aerial photography and mapping projects that are part of the graphic portion of the MPLIS.

Many other local government offices often conduct surveying activities. These offices include those involved in engineering, public works, utility, zoning, and recreation. Private surveying, engineering, and even land title firms maintain substantial land survey data bases, but they are often reluctant to share information they see as providing a competitive advantage. These private firms may be willing to share the data with government, but they are concerned that open record laws will allow their competitors to capture data from government with very little cost.

Vertical survey data provide the base for elevation, slope, and drainage information. The importance of these vertical data is increasing in direct proportion to the increase in concern and controls related to environmental hazards and water quality. Historical and archeological information may also be important in certain areas.

GRAPHIC DATA

Graphic data come in a variety of forms, including maps, photographs, drawings, and images (such as digital orthophotographs that include characteristics of traditional maps, photographs, and digitally generated images).

There are two aspects of graphic data for an MPLIS. One is current data that are stored on hardcopy maps or other graphic materials. These graphic materials can often be digitized and thereby used as input to the graphics base of an MPLIS. The second aspect of graphic data is output that can be created and displayed as output from an MPLIS. The graphic outputs of an MPLIS may range from a simple map containing an index to nongraphic parcel data to a complex, multi-layered overlay of many different land data files.

A wide variety of maps, drawings, and images can be used in an MPLIS. Maps range from large (e.g., 1:500) to small (e.g., 1:100,000) scales. Maps may cover all of an area or only a small portion thereof. Graphic information may be as detailed as a reference map to a particular area or as simple as a thematic map designated to convey information about only a single topic or subject area.

For example a graphic image may show:

- planimetric or topographic features,
- surveys, subsurface features such as groundwater or geology,
- population, land use, or other cultural data, or

political or statistical boundaries such as county, city, state, census tracts, voting districts, taxation districts, or traffic zones.

Drawings of interest for an MPLIS usually pertain to planning and engineering tasks. Recorded plats almost always are a key component in building and maintaining parcel and base maps. Utility design and as-built drawings are essential for maintaining a utility or infrastructure layer. A few examples of sharing of graphic data between government, utilities, and the private sector are now starting to appear.

Photographs, video, and other image media have a strong potential to contribute to an MPLIS, but their use in government, particularly at the local level, is the exception rather than the rule at the present time. However, the use of image media is growing. Photographs and video have been used to document land value appraisal. Videos are also being used to record the condition of roads (i.e., photologging) and the condition of sewers and other underground pipes. Computer systems are now available (and in use in a few jurisdictions) that support the integration of video images, maps, drawings, and nongraphic data, thereby improving access to these data and increasing the flexibility of their use.

SOURCES OF GRAPHIC DATA

Graphic data resources can be found in many local, regional, state, and federal government offices and in many private companies. The sources of graphic data are important in the design of an MPLIS, as well as in consideration of how the data base that is an integral part of the system will be maintained. These graphic data can be grouped into four categories, based on who creates and maintains them and the purpose for which they are generated.

1. *Graphic data that are created and routinely maintained by local governments themselves.* Among data in this category are large scale maps and images, such as property appraiser's parcel maps, compiled subdivision maps, a set of aerial photographs, a medium to small scale (1" = 1,000' to 1" = 5,000') map set, and a street atlas. Also, local governments often have "overlay" maps to which zoning or utility data have been added to one of their basic graphic data bases. These map series are valuable, often representing years of transactions to the data base in a

graphic form. The information is critical to the operation of local government and difficult to reproduce. Since these data are typically the product of the efforts of many individuals over a relatively long period of time, the data vary in quality due to varying standards and specifications. In spite of these shortcomings, they are easy to use and are used widely.

2. *Drawings, aerial photographs, and maps that are submitted by applicants as part of regulatory processes.* These materials are part of site plan reviews, subdivision reviews, re-zoning applications, and the enforcement of various codes. These graphic products play a major role in the update and maintenance of the graphic data side of an MPLIS.

3. *Drawings, images, and maps that are acquired by government for a particular project or purpose.* These graphic materials may enhance the data created as part of the first two preceding categories by adding detail, accuracy, or currency to a particular area. Because of their accuracy, detail, and currency, these data are often useful in building the initial graphic data base for an MPLIS.

4. *Maps and images created, maintained, and published by other organizations.* These organizations include private companies and regional, state, and federal agencies. The graphics are typically available as paper copy, but the publication of the graphics in digital formats is increasing. Among the graphic data that are available to local government from other agencies and companies are:

- 7-1/2 minute quadrangle maps from the U.S. Geological Survey
- Soils maps from the U.S. Soil Conservation Service
- National Wetlands Inventory from the U.S. Soil Conservation Service
- Demographic maps from the U.S. Bureau of the Census
- Flood prone area maps from the Federal Emergency Management Agency (FEMA)

PARCEL INDEX MAP

One of the most important maps generated and maintained by local government (i.e., category 1 above) is a parcel index map. This map typically shows the boundaries and identifying number for each parcel of land in their jurisdiction. This is an index to the contents of land record files and should be available in each office of local government that maintains land record files. A parcel index map is helpful in both filing data in the system and retrieving data from the system. It is particularly useful to citizens who are infrequent users of the system.

CURRENT LAND DATA REQUIREMENTS

An inspection of the kinds of data currently maintained and used by local government is one measure or view of the data needs of an MPLIS. As indicated by Figure 9-1, parcel data (on the right side of the figure), are a major component of an MPLIS. At the local government level, parcel data are the most frequently occurring and most frequently used class of data. Examples of functions that rely heavily on parcel data at the local level include:

- property appraisal
- title recording
- building inspection
- emergency vehicle dispatch
- zoning and planning
- land surveying
- utility planning and management
- voter registration.

Parcel data actually contain several kinds of parcels. Zoning parcels may vary from ownership parcels (i.e., they may not be coterminous, with two or more parts of an ownership parcel having different zoning). Appraisal and utility parcel maps may also vary, with multiple units or multiple service units located on one ownership parcel.

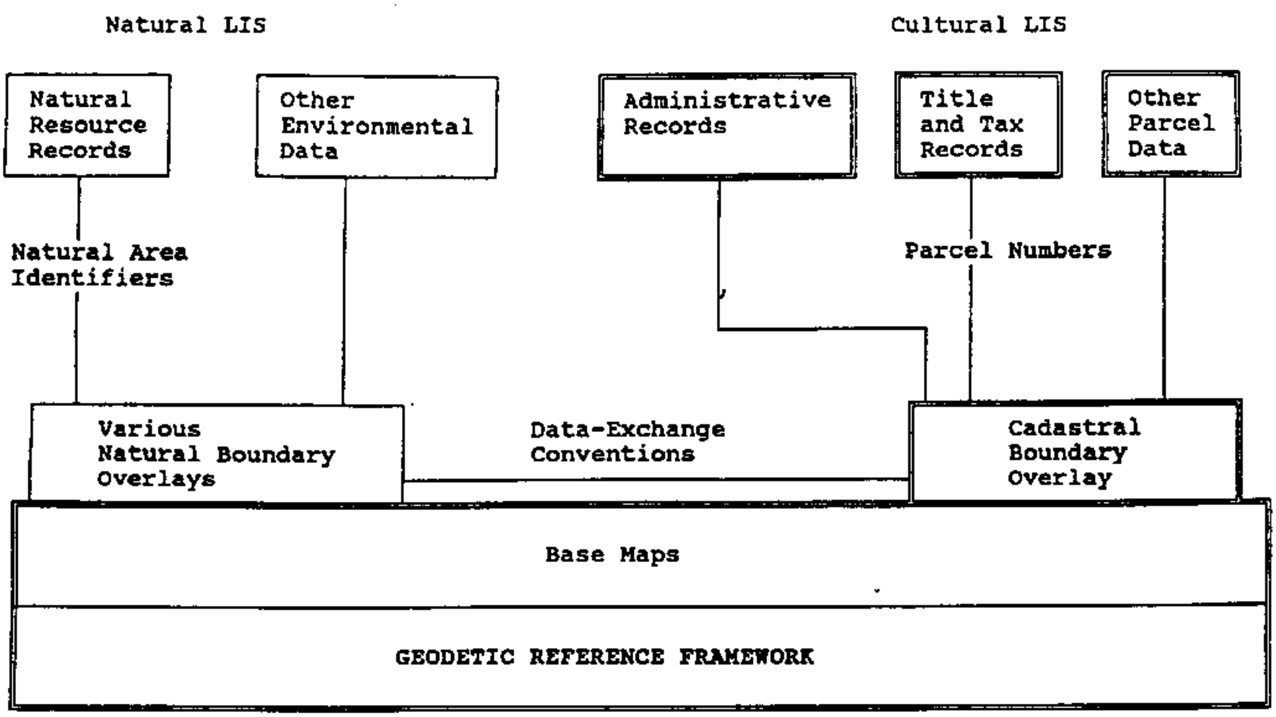

Figure 9-1: Components of a MPLIS (from NRC, Procedures and Standards for a Multipurpose Cadastre, 1983)

In addition to parcel data, some local government functions also use polygon data. For example, property appraisal may use resource polygon data (e.g., for soils, depth to bedrock, or depth to groundwater) as a data resource to assist in appraising the value of an ownership parcel. Planning functions may require the use of both ownership parcel and resource polygon data as well. Such planning may use soils and other resource polygon data as well as polygons developed as part of the planning process itself, such as for school districts, water districts, and watersheds.

FUTURE LAND DATA REQUIREMENTS

The development of a detailed inventory of future land data requirements is a task that is rife with uncertainties. However, the appearance of new requirements in the future is a certainty. New mandates and new opportunities to manage physical resources more effectively will continue to appear. These mandates and opportunities will impact on local and state government, as well as private sector data systems users. It is thus safe to say that the MPLIS of the future will:

- require a large volume of data
- require more detailed data
- be subject to more frequent use
- have much greater impacts on the decision-making process
- have much greater impacts on individual users of the results that the LIS produces.

Therefore, the best approach is to build the most complete, most accurate, data base possible, in order to effectively serve these as-yet-unknown future needs. Future demands for accurate data systems make it very important that each MPLIS be built on a sound foundation of accurate geodetic control. Current technology makes such a foundation affordable and future demands for data and analyses will provide substantial benefits to those who make the relatively small additional investment for accurate geodetic control.

MANAGEMENT OF LAND DATA

A major task in the development of an MPLIS is management of the land data, including access, security, confidentiality, quality control, and maintenance. A short discussion of each of these topics follows here with more detailed discussion to appear in later chapters.

ACCESS TO LAND DATA

Improvement in accessibility to data is one of the major objectives of developers of an MPLIS. In the past, and currently in most jurisdictions, access was closely tied to storage equipment and methods for land information. It is assumed that much of the data in an MPLIS will be stored in a computer in digital format. However, in order to fully understand current and future needs, and provide access to all users, a full understanding of the storage and retrieval media for data is necessary.

STORAGE AND RETRIEVAL MEDIA

The media used to store data is a basic factor in accessibility. Currently, textual records are stored on a wide variety of media.

Each medium has a number of physical characteristics that affect the useful life of the data; the space, equipment, and procedures that are used to store, retrieve, duplicate, update, and distribute the data; and the suitability of the data for specific user needs, whether it be merely reading the file, summarizing the data in the file, or performing a detailed analysis.

Paper has been and, in most jurisdictions, continues to be the most common medium for public records. Most land information users are familiar with paper records and many legislatures require that paper copies be maintained and available to the public. However, many statutes are being changed and the opportunities to convert records from paper to film and digital media are increasing.

Conversion from paper to other media reduces space and storage costs, sometimes by as much as 90 percent. Retrieval of paper documents from off-site locations is another cost that can be reduced by switching to other media.

Mylar, vellum, linen, and film have all found traditional uses for maps and drawings. These materials contain much graphic material, but also contain nongraphic information as well. Since these media are generally more stable than paper copies, they provide an important base for reproduction of copies for a variety of users. Variation in initial costs, copy costs, update costs, and costs to the user all need to be considered in evaluating various media resources.

Data storage via electronic media is expanding rapidly. Electronic media include not only magnetic tape and diskettes typically used with smaller computer systems, but also hard disks, optical disks, and compact disks (CDs). These methods are the media of choice for the vast majority of MPLIS data.

The most important reason for the move to electronic media is the speed and flexibility they provide for storage, retrieval, display, and analysis. A computerized system is capable of using a single entry to locate via a number of cross references and a nearly limitless variety of section criteria, and to display the results in either summary or detailed formats. As long as records are properly coded, they are relatively safe from loss or misfiling, especially compared to paper records. Electronic media also provide flexibility, particularly as to map data, by allowing the display at a wide variety of scales.

QUALITY CONTROL

If users of an MPLIS are to be confident in the contents of the system, standards of quality concerning the file content must be clearly understood. Such confidence is important both to encourage system use by all potential users and to obtain the cooperation necessary on data maintenance activities. Chapter 20 provides details on standards and specifications that should be considered. A few basic suggestions are included here to help ensure the basic data needs of the users of an MPLIS are met.

Quality control standards for the MPLIS should include spatial accuracy as well as validity of specific data items. One approach that is useful, particularly when building the initial data base for an MPLIS, is to include the qualifications (or limitations) on how the data can be used as part of the data file. This "truth in labeling" approach thereby allows the data base to be built more quickly than if specific criteria were set as limits of entry. Responsibility for assigning limitations can reasonably be placed with the office or unit that originally places the data in the system. This labeling technique can also be used to explain how and why data are available, or are not available to all systems users. This truth in labeling approach is used in the draft Spatial Data Transfer Standard (SDTS), recently released by the National Institute of Standards and Technology (NIST) (SDTS, version 12/90).

SECURITY, OPEN RECORDS, AND PRIVACY

Limits on access to government records are regulated by a variety of freedom of information and privacy statutes and ordinances. Problems of confidentiality in land information systems can be limited by only placing information that is public in the system. These public records need to be accessible to all data users and should also be correctable by the individuals involved (e.g., owners and leasers). Access to confidential information is limited to the agencies that are responsible for the information. Such information is segregated and protected from the open and accessible files that also make up the system. In some cases, aggregations of restricted data may be linked with public records, but all detail and specific information remain confidential.

Many types of parcel data, such as title records, require procedures to assure that individual records are secure and that information on the date and time of any changes is maintained as part of the permanent file. To fulfill these requirements, procedures need to be devised that assign responsibility for specific tasks (i.e., develop an audit trail), restrict access to some data in the records, prevent unauthorized changes, prevent loss of records (and/or assure that a back-up file is available), and minimize the possibility of malfeasance, as well as inadvertent errors and changes to records.

In manual record systems, security can be assured by placing records in a secure location, restricting access to authorized personnel, and maintaining information on people who do have access to the records. The problems of security in computerized systems increase substantially, but a much wider variety of measures can be employed to assure such security. In particular, access to certain tables in an assessment system may be restricted to prevent unauthorized persons from changing valuations. Similarly, access to data about finances of individuals and companies is often restricted due to such information being excluded from the public record. Transaction logs or journals may also be maintained, to provide "audit trails" about each change, noting what change was made, when it was made, and who made it.

MAINTENANCE OF DATA BASE

Ultimately, the requirements of users of data in the MPLIS depend on the regular, dependable maintenance of the data base on which the system relies. A careful review of data needs will usually reveal a wide range of data that users will frequently request (see Chapter 16). No matter how convincing the arguments for including data may be, there is one over-riding principle that must be considered: If you don't have the resources (time, money, people, and equipment) to maintain a data file, don't include it when building the initial data base. Loss of confidence in a system due to incomplete, out-of-date, inaccurate data is a failure that can be extremely damaging, or even fatal, to your MPLIS development efforts.

SUMMARY

While recognizing the requirements of other sectors, this chapter focuses on the data types and needs of local government, current and future.

Two kinds of data, graphic and nongraphic, are basic categories of land data found in land information systems. Suggestions as to how development of an MPLIS and the new demands on government are affecting the data needs of local government are also considered.

The chapter concludes that data requirements of local government are evolving, due to changing resource management needs and the availability of new technologies, many of which support the development and use of MPLIS. Because of the critical importance of the data base in the MPLIS, it is recommended that a detailed needs assessment (see Chapter 16), be completed before embarking on the implementation of an MPLIS.

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10 DATA LINKAGES IN AN MPLIS

Timothy L. Nyerges

INTRODUCTION

A multipurpose land information system (MPLIS) commonly consists of a set of interconnected data bases to support operational information applications. Examples of those applications include review of land development permits, street maintenance scheduling, and health center facilities location. The extensive investment that local governments have made in computerizing data over the last 30 years prohibits a complete restructuring of data bases to create a single data base to support such application environments. Combining all information into a single data base would create a land information management nightmare from an institutional perspective, and adversely impact the applications for which the systems were originally built. However, the diversity in applications of data does not prohibit an organization from bringing together diverse sets of data for more effective use. As long as data contain a data linkage among the elements, there is no need to combine all location-related data into a single data base. Whether the data linkage is to support a tight or loose integration of information, a carefully devised plan, including a justification for developing data linkages, can help create a fully interactive, interconnective set of data bases (Nyerges 1989).

Data linkages are important for several reasons. Technically, data linkages can reduce or eliminate redundancy by systematically relating various data sets. The data linkage can support easy access to data when such access is permitted. Economically, data linkages reduce the cost of data maintenance, and information use becomes more effective through a broadened information context. Institutionally, data linkages tend to foster cooperation among parts of an organization (or organizations) regarding land information issues.

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THE NATURE OF DATA IN AN MPLIS

The raw data stored in an MPLIS data base can be described using three fundamental categories of characteristics: spatial, thematic, and temporal. Spatial data include geographic shape information in terms of x,y geometry, as well as relative location information in terms of topological information as shown in Figure 10-1. Topological information deals with adjacency considerations such as what is next to what in space -- e.g., parcels or blocks -- and what is connected to what across space -- e.g., parcel boundary intersections or roadway intersections.

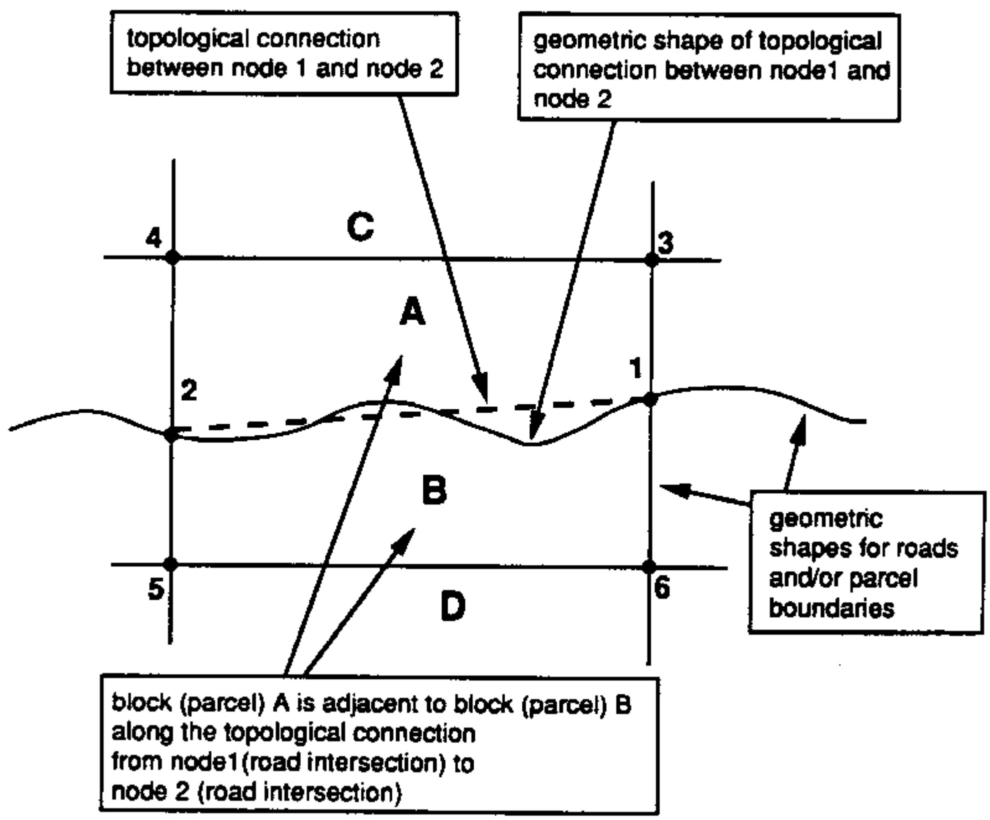


Figure 10-1: Topological information for parcel and roadway data.

Thematic attribute data include the qualities and quantities describing phenomena other than space and time -- e.g., the tax and ownership information for parcels, and the volume of traffic on a roadway. Thematic attribute data have tended to be a "catch-all" or "other" category because of the variety of data possible. Thematic attribute data constitute most of the data in most information systems. Hereafter the term "attribute" will be used without the qualifier "thematic" as is commonly accepted in a GIS context, but the reader should be aware that "thematic attribute" is what is meant, rather than spatial attribute or temporal attribute. Perhaps at some time in the future, the inconsistency in this terminology will be clarified.

Temporal data include the different aspects of time that can be measured in various contexts. For example, world time deals with time according to the sequence of events for day-to-day activities as measured by a wall clock (or calendar). Data base time deals with the time certain information is entered into a data base. In yet another context, computer time concerns the time it takes to process a computer program, several of which are sharing the processing unit. In current systems, world time is usually included as part of the thematic character of phenomena because this dimension has not yet received separate attention in the development of the GIS/LIS technology. In many applications such as infrastructure maintenance, land development permitting, and land use change, the temporal characteristic is of significance to the results of analysis. More than likely, the formal treatment of time will improve as its treatment becomes better understood conceptually to direct GIS/LIS implementations (Langran and Chrisman 1988).

Whatever the nature of data representations, all three aspects -- space, theme, and time -- are required for complete descriptions of real-world phenomena. Complete descriptions support information processing better than do incomplete descriptions. If one of the aspects is lacking, incomplete descriptions result, potentially limiting information processing. The nature of data representations to be stored in an MPLIS is determined through a process of data base design.

MPLIS data bases are designed from both a logical and physical perspective. A logical data base design focuses on the needs of users and their requirements for certain data. Logical data base designs are guided by applications, administration, or some other fundamental constraint. A physical data base design focuses on the advantages for processing performance and maintenance of data. Computer programming requirements and disk resources guide physical data base design. The focus in this chapter concerns data linkages to support logical data base designs. Physical data base design is beyond the intended scope of this chapter.

Logical data base designs specify the grouping of spatial, thematic, and temporal data. The terms "records" and "files" are often used to refer to the groups of data. However, the reader should be aware, as in any information system including MPLISs, there is a significant difference between "logical records" and "physical records," as well as "logical files" and "physical files." Logical records represent data in a way that is convenient to an application. Physical records are determined by the manufacturer of the computer operating system and require data to be stored on disk in a certain way. Since the focus in this chapter concerns data linkages as part of logical data base design, emphasis is on logical records and logical files. When reference to both records and files is meant, the term "data group" is used.

MPLIS spatial and thematic data groups, as well as the linkages among them, are created to satisfy the needs of one or more applications. Certain applications have a need for certain data to be related to other data in order to process them effectively to create information products. Data groups for parcel information and highway networks constitute the basic examples in this chapter, but data groups for any land information are pertinent in this discussion.

THE NATURE OF A DATA LINKAGE

Data linkages among separate data groups are necessary to establish and maintain the full character of phenomena to be used in information processing. Such data linkages are meant to span the administrative partitioning of information within and betweenorganizations. A data linkage is a reference from one data groupto another that allows information access across data groups. Conventionally, a linkage is used for referencing between records. For example, a data linkage can be created between the spatial data describing the location of a parcel (as stored in one record of a spatial data file) with the attribute data describing ownership of the parcel (as stored in a record in a different file). Each of the files can even reside on two different computer systems, but the reference should be bidirectional -- i.e., from one data group (record and file) to a second, and from the second data group back to the first -- rather than unidirectional. Although a unidirectional reference is better than none, a bidirectional linkage allows access to data from any data viewpoint. The latter criterion is essential in an information system when many access paths to data are unknown before analysis begins.

Many data linkages are implemented using identifiers, while others can be implemented using computer storage address pointers. Both identifiers and pointers are codes for accessing information, but they are implemented in different contexts. Identifiers can refer to locations or to arbitrary names, and are implemented by applications specialists as logical data base designers. Computer storage address pointers are a topic for physical data base design, for they are implemented by programmers and are beyond the technical scope of this chapter.

Identifiers provide an explicit approach to data linkage, with the codes for these identifiers being easily interpretable by applications specialists. (Even a citizen interested in how data are referenced by public agencies should be able to understand an identifier.) Explicit data linkages support well established references between data groups, as determined by information needs of an organization. In an MPLIS an explicit data linkage does not take the place of a coordinate reference system used as an implicit data linkage (such as in data layer overlay). Rather, the two approaches complement each other. Data linkages as spatial coincidence established through data layer overlay are discussed in Chapter 11.

Because a land information system can be examined from at least three perspectives -- technical, economic, and institutional (Dueker 1987b) -- any component of such a system can also beexamined from those three perspectives. A data linkage, therefore, can be said to involve technical, economic, and institutional considerations. The technical considerations include the nature of the linkage -- i.e., what it is and how it is implemented. The economic considerations concern the benefits and costs of implementing and maintaining linkages. The institutional considerations include privacy and security issues as well as the organizational support that will enhance or constrain the linkages.

TECHNICAL CONSIDERATIONS FOR DATA LINKAGES

Four technical considerations are important. The first concerns representation. The second concerns data grouping according to data base objects. The third deals with how linkages are implemented using data base keys. The fourth consideration involves data quality issues.

REPRESENTATION CONSIDERATIONS: WHAT'S IN A LINK?

Information representation deals with how to describe the character of a data linkage. For an MPLIS, information representation takes place in three contexts: a) meaning, specified by using entity definitions and the geographically distributed phenomena such as land parcels they are intended to describe -- i.e., using entity identifiers; b) data structures, specified by using data base objects such as polygons -- i.e., using data base object identifiers; and c) visual character, specified by using graphic symbols such as dashed or solid lines -- i.e., using graphic symbol identifiers.

Generally, each context concerns a set of identifiers to establish efficient and effective information use. Identifiers for information can be described in all three contexts, where sometimes they refer to the same element of information, but at other times do not. For example, an entity identifier refers to a specific land parcel in the world, whereas a data base object identifier refers to a polygon stored in a data base, and a graphical symbol identifier refers to a shade pattern that graphically depicts the area of the polygon (hence parcel). It is important to distinguish between these three contexts to clarify what a link represents.

The nature of an identifier is influenced by each of the representation contexts: entities, data base objects, and graphical symbols. An important example of an identifier in an MPLIS is a parcel identifier that references parcel information. In the context of the entity representation, a parcel identifier provides access to information about a parcel, including information in tax registers that contain the attribute descriptions for a parcel. It does not necessarily matter how that identifier is implemented for information processing; what matters is that the identifier distinguishes one parcel (or entity) from all other parcels (or other entities). However, a parcel identifier that can be interpreted by applications specialists (such as the location reference to section, township, range, and lot number) is sometimes more useful since it plays a dual role of both unique identification and location. In the context of a polygon data base object, an identifier as a polygon code -- e.g., an integer sequence built from coordinates -- will distinguish one polygon from another. The polygon may or may not be a parcel; it may be a census block. The nature of polygon identifiers influences how manipulable the information is for computer algorithms, rather than for humans. An identifier for a graphical symbol differentiates one symbol from another; that symbol graphically depicts the polygon, which, in turn, represents the parcel.

Criteria from each of the three representation contexts weigh in the decision on what is best chosen as an identifier to represent a data linkage, but some considerations regarding parcel entities are weighted more heavily than those for polygons, and those for polygons are weighted more heavily than those for symbols. The entity context and the data base object context are important for this discussion of data linkages. Graphical symbol identifiers are important in an MPLIS as annotation on maps and reports, but such annotations will not be treated further in this chapter because that involves human visual processing rather than computer processing.

Parcels

Representing entities or data base objects is complicated in some instances by the need to distinguish parcel-type information from network-type information. In an entity representation context, a land parcel is a real-world phenomenon that is of basic importance to many applications in local governments. However, different kinds of parcels exist, depending on the function of an organization (Horning 1990). For example, a tax parcel maintained by an assessor may not, in fact, be equal to a development parcel maintained by a building and development department, and an ownership parcel may be different from both the development and tax parcels. Entity definitions provide the explicit character of both, and these differences in character must be recognized to avoid confusion when decisions are made, or when data are borrowed and/or shared among parts of an organization.

Both computerized and manual filing systems require some way of identifying parcel entities. A parcel identifier is a code for recognizing, identifying, selecting, and arranging information to facilitate organized storage and retrieval of parcel data records. In addition, if the parcel data are partitioned among spatial, attribute, and temporal data files/records, then the same identifier should be used for these files/records to facilitate data linkage.

Three forms of parcel identifiers are common (National Research Council 1983, p. 63):

1. Name-related identifier -- often a grantor-grantee alphabetized code -- not recommended in an automated system because it does not necessarily result in a unique identifier,

2. Abstract, alphanumeric identifier -- often random numbers (without duplication) associated with parcels such as a tract index, and

3. Location identifier -- a geographic code (geocode) related to location.

Location identifiers themselves are also of three types:

1. Hierarchical identifier -- based on graded political units such as the Public Land Survey System (PLSS),

2. Coordinate identifier -- a point coordinate (in a state plane coordinate system or latitude/longitude system) within or on the boundary of the parcel, and

3. Hybrid identifier -- a combination of location graded units and coordinates such as PLSS and state plane coordinates.

Criteria for choosing an identifier take into consideration both the initial selection as well as the maintenance of the identifier. In this regard, a parcel identifier should exhibit at least the following characteristics (National Research Council 1983, p. 63):

1. Uniqueness -- one and only one parcel should have any single identifier,

2. Simplicity -- identifier should be easily understandable and usable by the public,

3. Flexibility -- the identifier should be usable in a number of contexts,

4. Permanence -- the identifier system should not be subject to change or disruption,

5. Economy -- the implementation costs and maintenance costs should not be unreasonable, and

6. Accessibility -- the identifier should be easily obtainable.

Oftentimes a single parcel identifier is not feasible because of institutional histories. If multiple identifiers are used, a cross-index must facilitate storage and retrieval of the same parcel regardless of the naming system. This is particularly true across local government agencies, but also might be the case within an agency. For example, "street address" and "section, plat, and lot number" should have a cross-reference in a look-up table. However, one of the identifiers should be institutionally recognized as the principal one. Commonly the principal one is legally defined by title according to the recorder of deeds.

Data linkages can be established for parcels at different levels of geographic resolution. Some of these might be: a) an address linked to a parcel centroid, b) a block face address range linked to a street segment with all parcels along the block face, and c) an area block, tract, or district linked to all parcels within the area of interest.

Networks

A second, more complicated example of representation for data linkage in an MPLIS deals with (transportation) network information -- i.e., information about highways and rivers. Entity identifiers for highway networks commonly take two forms: a "control-section" designation or a "route-name and milepost" (point) designation. Street-name and street addresses are very similar to the route-name and milepost, but the metric along the highway for mileposts is usually more systematic than are addresses. In the case of rivers, a river stretch provides a fixed location reference for control-sections, whereas river name and measuring stations provide a relative distance referencing system.

The control-section scheme is based on a fixed length of the highway or river being characterized by homogeneous attribute values. An identifier is assigned to the control-section to distinguish it from other control-sections. The conventions for establishing the identifiers often depend on the application, but generally a district name and reference number suffice to differentiate them. Different application groups in an organization may have different control-sections -- one for pavement management and another for highway performance monitoring, or one for sewage effluent and another for toxic chemicals. Each segmentation is homogeneous with respect to the attribute(s) of interest to an application. Using fixed-length control-section segments prohibits discrimination of any section shorter than each control-section, and causes considerable data redundancy across applications. Unfortunately, this makes data linkage among diverse applications difficult, requiring solutions to the line overlay problem for each retrieval. The solution comes in the form of a suitable referencing scheme for variable distance sampling of attribute values, and a processing approach - called dynamic segmentation -- that takes advantage of the referencing scheme.

A solution to the referencing problem for variable sampling of attribute values along a linear entity is to use a route-name and observation-point identifier scheme. The scheme works well for point-oriented observations along a linear entity as well as for line-oriented observations that start and stop at various places along the linear entity. Examples of the former where such a scheme is useful are accidents, culverts, signs, and similar occurrences at various locations along highways. Examples of the latter are pavement condition, type, depth, and width, for these characteristics begin and end at various locations along the highway. The same can be said for rivers where certain events are recorded at points along a river, and for variable stretches of the river where flows are to be described.

Milepoint and station point references provide the relative distance reference along the length of highway/river line geometry. Dynamic segmentation (Dueker 1987a) software uses the relative distance reference to produce segments of the line that correspond to homogeneous attribute descriptions. That is, each of the attribute values applies to a newly segmented portion of the line to be used for display and/or analysis purposes.

In the entity representation context, data linkage is supported by identifiers that have meaning to applications within an organization. These same identifiers can be transferred to the data base object context to provide the implementation character of a data linkage. It is also possible to construct data linkages from arbitrarily devised identifiers that have meaning only in a data linkage implementation. For example, integer numbers assigned in a sequence can be used for processing, but these are less effective for institutional contexts where entity-oriented identifiers have already been established. However, integer-sequenced identifiers are commonly constructed by software processing rather than by humans and are used to link spatial data base object types such as polygons with thematic data when other, more meaningful identifiers are not available. Regardless of the meaning of the identifier, both the integer and the entity-based identifiers are implemented for data base objects using data structures and processes set up by MPLIS software designers. The designers might be the vendors of the software or the in-house applications software staff. Regardless of design and implementation, the linkages must be continually maintained to ensure consistent and effective information retrieval.

DATA GROUPING CONSIDERATIONS: DATA BASE OBJECTS

Concerns with spatial and attribute representation occur in a data base object context as illustrated in Figure 10-2. A point is defined by a coordinate. A node is a topological junction. A line segment is a set of connected points. A link is a set of connected nodes. A chain is a connected sequence of line segments with nodes at both ends. A ring is a mathematical construct for a closed chain of line segments (points) around an area. A polygon is an (interior) area enclosed by a ring. A polygon is a mathematical (geometrical) construct useful as a general term for describing an entity of the world such as a parcel. A label point is used as a location identifier for the interior of a polygon. Detailed descriptions of these spatial object types are provided in the proposed National Spatial Data Transfer Standard (National Institute of Standards and Technology 1991) to be maintained by the U. S. Geological Survey.

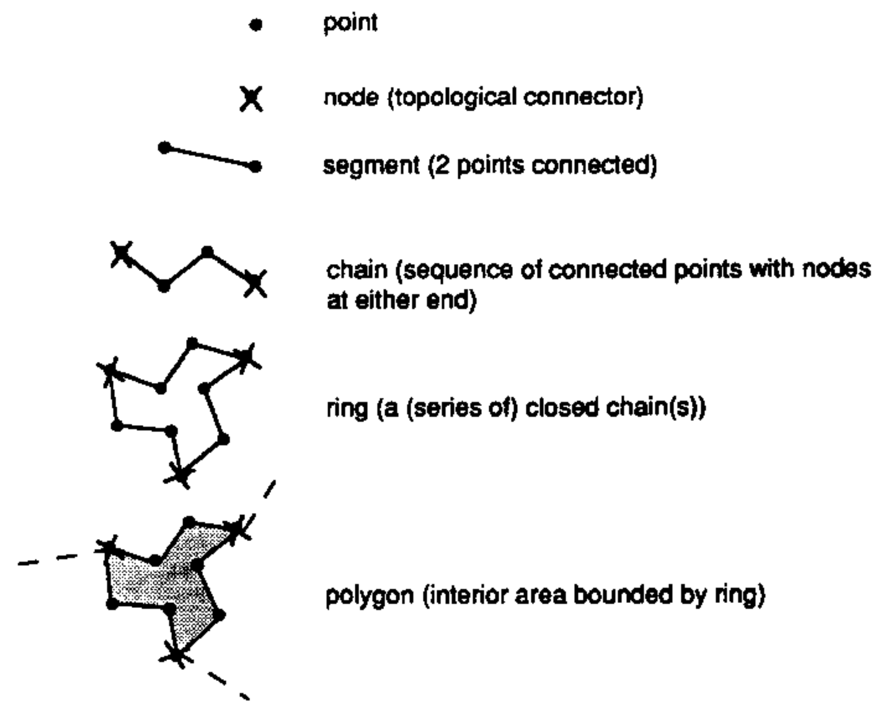


Figure 10-2: Graphic depiction of spatial database object types.

In many MPLISs, spatial data (describing the spatial object types described above) and attribute data (describing the qualities and quantities of entities) are grouped into separate records/files for several reasons:

1. Spatial coordinates need to be accessed rapidly for display.

2. Attributes of spatial objects need to be modified rapidly.

3. Different parts of an organization have different responsibilities for maintaining data. The attribute data often exist in one or more data base management systems separate from the spatial data.

A solution for data linkage that embraces the separate data management strategies is to associate the different attribute data to spatial data, maintaining a one-to-one (or one-to-many) correspondence of the spatial data with the attribute data as shown in Figure 10-3.

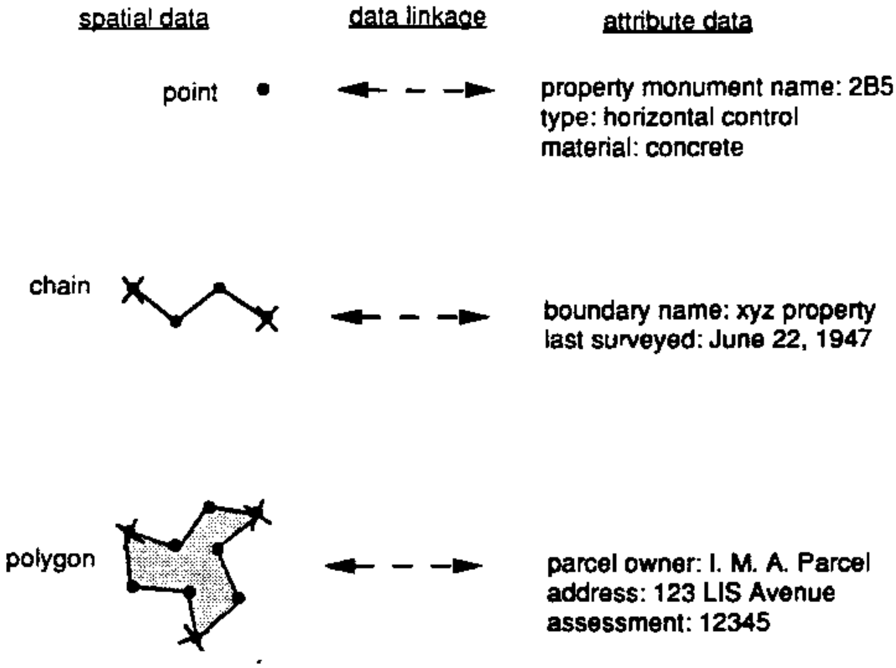


Figure 10-3: Spatial and thematic attribute data linkage for parcel information.

Maintenance of the one-to-one correspondence is relatively simple for attribute values associated with a single point, chain or polygon spatial object, but more difficult for spatial objects whose attributes vary linearly along the length of the object -- e.g., a highway or river. For example, to represent the nature of three attributes changing along a stretch, three separate segmentations must be used for the same stretch of highway as illustrated in Figure 10- 4. Maintaining separate segmentations -- i.e., the actual coordinates of all three chains -- would add tremendous data redundancy in a system. This can be avoided by a data linkage that makes use of three spatial reference schemes and is processed with software that can perform dynamic segmentation (Dueker 1987a).

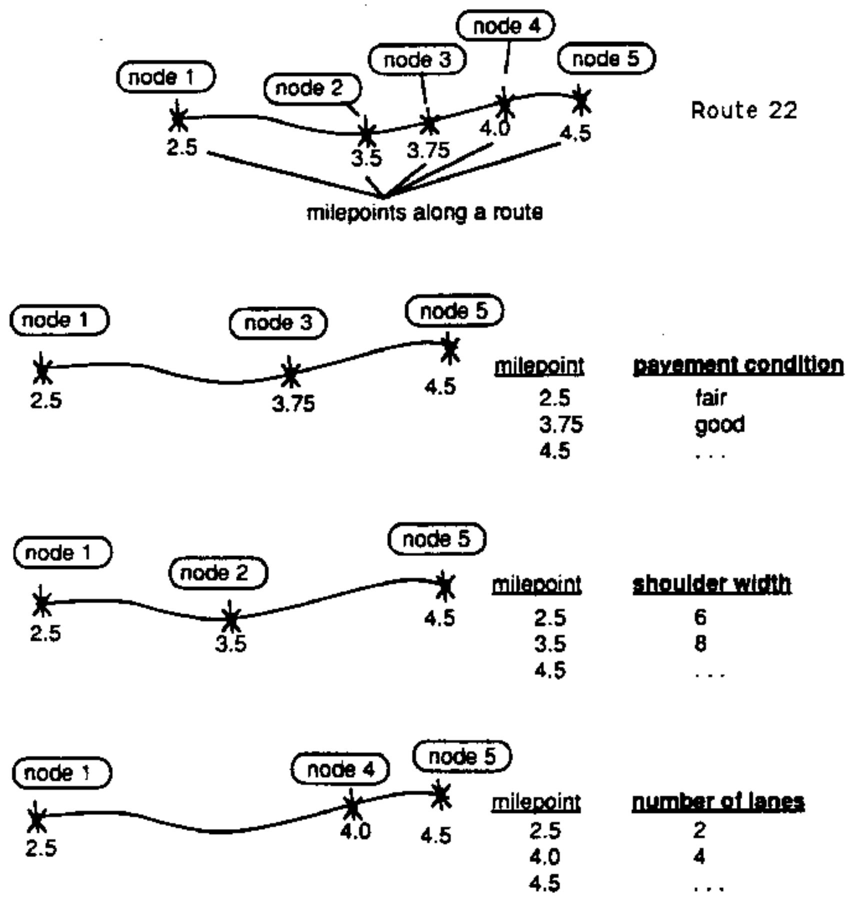


Figure 10-4: Multiple (six) chains required over the same stretch of highway to support three attributes. Two chains are required for every segmentation in this example. A node occurs at every milepoint where a change in attribute occurs.

A data linkage for linear objects that minimizes data redundancy requires a combination of three reference schemes (Nyerges 1990): 1) topological representation, 2) a sequence of x,y coordinates for linear geometry embedded in a coordinate system, and 3) route and milepcint references to the beginning and ending nodes of the chain as well as a distance function along the chain to adjust mileages (See Fig. 10-5).

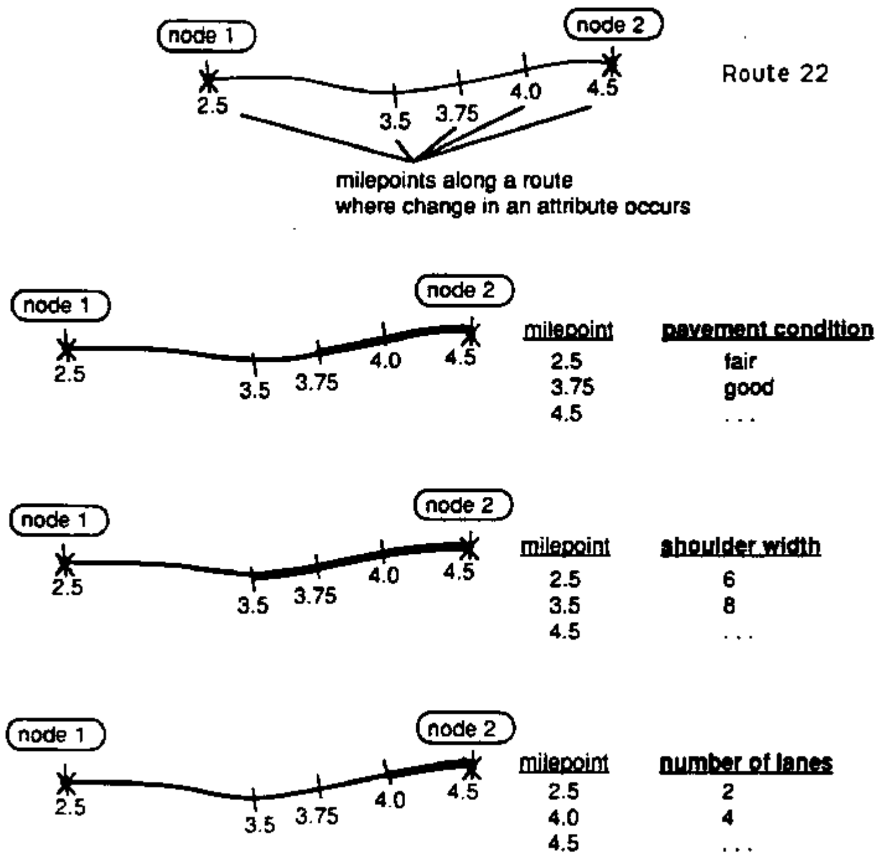


Figure 10-5: Variable segmentation of a single chain to support three different attributes.

IMPLEMENTATION CONSIDERATIONS: DATA BASE KEYS

Data base keys are used to implement linkages between spatial, attribute, and temporal data records. Keys are of three basic kinds: primary, secondary, and foreign as shown in Figure 10-6. A primary key uniquely identifies a data record for retrieval (tuples and records taken to be of a similar nature). A parcel location identifier is often implemented as a primary key in a data management environment. The key is called primary because it is the principal means of accessing the record (tuple) for data processing purposes. All other data contents in the record depend principally on the primary key for retrieval. A secondary key is used as an alternative key to the primary key for accessing data in the same record, but the secondary key may have values that are not unique (See Fig. 10-6). That is, when data are accessed via a secondary key, several records could be retrieved.

A foreign key is used in two ways, it implements a data linkage between a spatial data record (such as a chain) and an attribute data record (containing the attributes of an entity), and it implements a reference to a primary key in another data record of the same type or different type -- e.g., when a parcel record references a street record (See Fig. 10-6). The two data records are often maintained in different data management systems; e.g., spatial data are maintained by a spatial data management system and attribute data are maintained in a relational data management system.

Parcel Attribute Records

Primary (unique value)	Secondary (nonunique value)	other data items	Foreign (unique value)
Parcel ID 32	Census tract ID		Street section ID 144
⋮	⋮	⋮	⋮

Street Section Attribute Records

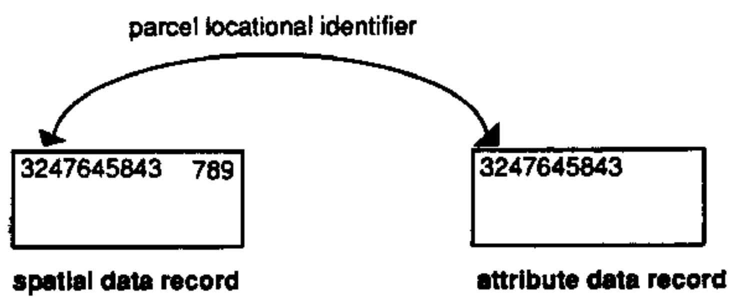
Primary (unique value)	Secondary (nonunique value)	Other data items
Street section ID 144	Census tract ID	
⋮	⋮	⋮

Figure 10-6: Primary, secondary and foreign keys for attribute records.

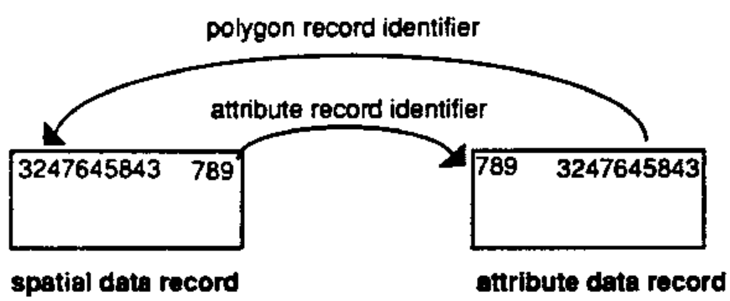
Several strategies are possible for dealing with linkages, depending on whether a one-to-one correspondence exists between spatial data records and attribute data records, or whether a single spatial data record is associated with several attribute records.

A single spatial data record -- e.g., points, polygons, and chains -- linked to a single attribute record is the simplest linkage to construct and maintain. The linkage established by embedding foreign keys supports a one-to-one correspondence of spatial and attribute records.

Several strategies are feasible. One strategy is to use the same key (such as a parcel identifier) in both records. A location identifier is often used as the single key, but an integer number would work as well as shown in Figure 10-7. This is easier to implement and maintain because of the minimum number of keys to be constructed.



(a) single parcel ID for both spatial and attribute records



(b) polygon identifer and attribute identifier embedded in corresponding records

Figure 10-7: Embedded keys–data links between data records for parcel information.

Another strategy is to embed the parcel identifier (as a primary key of the attribute data record) into the spatial data record and, conversely, embed the location identifier of the spatial data record into the attribute data record (See Figure 10-7). The advantages of embedding are fast retrieval and quality control. Keys are immediately available for processing when either the spatial data record or attribute data record are referenced; and embedding the key in the spatial or attribute data record rather than using a separate file of link indices gives a better chance that the key will remain current. The disadvantage is that embedded keys are not as easily maintained when key values are to be added, deleted, or changed to reorganize the data linkage.

Evolutionary development of information systems sometimes forces institutionalization of several identifiers, so that several keys must be maintained. This is not an optimal maintenance environment, but it is a realistic situation in many local governments because systems were implemented at different times. A linkage strategy that addresses that problem is to use a link

index as a separate storage mechanism rather than to use embedded keys. If information cannot be embedded in the data records for the spatial and attribute data records because of the number or frequent change, a cross-reference can be built that contains an integer number and a coordinate value for a location summary -- e.g., a centroid. These would be stored as a table with two entries (See Table 10-1). This strategy works well for points and polygons, for these spatial object types usually have singular location references.

The link index has several advantages. One advantage is that spatial and attribute data records can be stored in different systems with the physical interface effected mainly by two approaches. One approach is off-line tape transfer that requires a magnetic tape to be loaded when the data are needed. A second approach is by on-line communications networks, directly linking mass storage devices to the computers that perform the processing. In both approaches the logical interface can be developed using data transfer application programs. A second advantage is that spatial reference systems for the spatial data base objects do not have to correspond necessarily one-to-one with the kind of data base objects that are in the attribute file; a street file can be used to reference parcel information (See Table 10-1). A third advantage is that the link index can be maintained separately from the spatial objects file and the thematic attribute file, possibly reducing the cost of maintenance.

A chain spatial data object associated with nonhomogeneous attributes requires three spatial reference schemes for linkage tothe attributes. The three spatial reference schemes (topological chains, coordinates, and milepoints) stored in records enables interpolation along a chain at distances where the attribute values were

Table A. Link index for single attribute records with one or more parcels (parcel geocodes)

Attribute Record ID	Parcel Geocode
789	3247645843
790	0409097249
791	0000215032
792	1326581644
793	1326581644
794	1326581644

Table B. Link index for single street section linked to multiple parcels

Street (chain) ID	Parcel (polygon) ID
street_id_1	parcel_id_34
street_id_1	parcel_id_36
.	.
.	.
.	.
street_id_1	parcel_id_47
street_id_5	parcel_id_54
street_id_5	parcel_id_55
.	.
.	.
.	.
street_id_5	parcel_id_72

Table 10-1: Example Link Indices.

recorded. Figure 10-8 depicts a record structure and data linkage to retrieve and display highway data. Using this approach to spatial and attribute linkage obviates segmenting lines a priori (Nyerges 1990). The approach supports dynamic (run-time) segmentation (Dueker 1987a) and can be used to support segmentation oriented to display and/or analysis, rather than just to data capture. Milepoints and station point references provide the location reference along the length of a chain. A chain is the linear geometry for referencing the attribute data to a coordinate system. Dynamic segmentation software uses the relative distance reference to produce a segmentation of the chain that corresponds to homogeneous attribute descriptions. That is, each of the attribute values applies to a segmented portion of the chain. Furthermore, the segments are used in a temporary manner for display and/or analysis purposes only, unless a permanent file of that segmentation is requested.

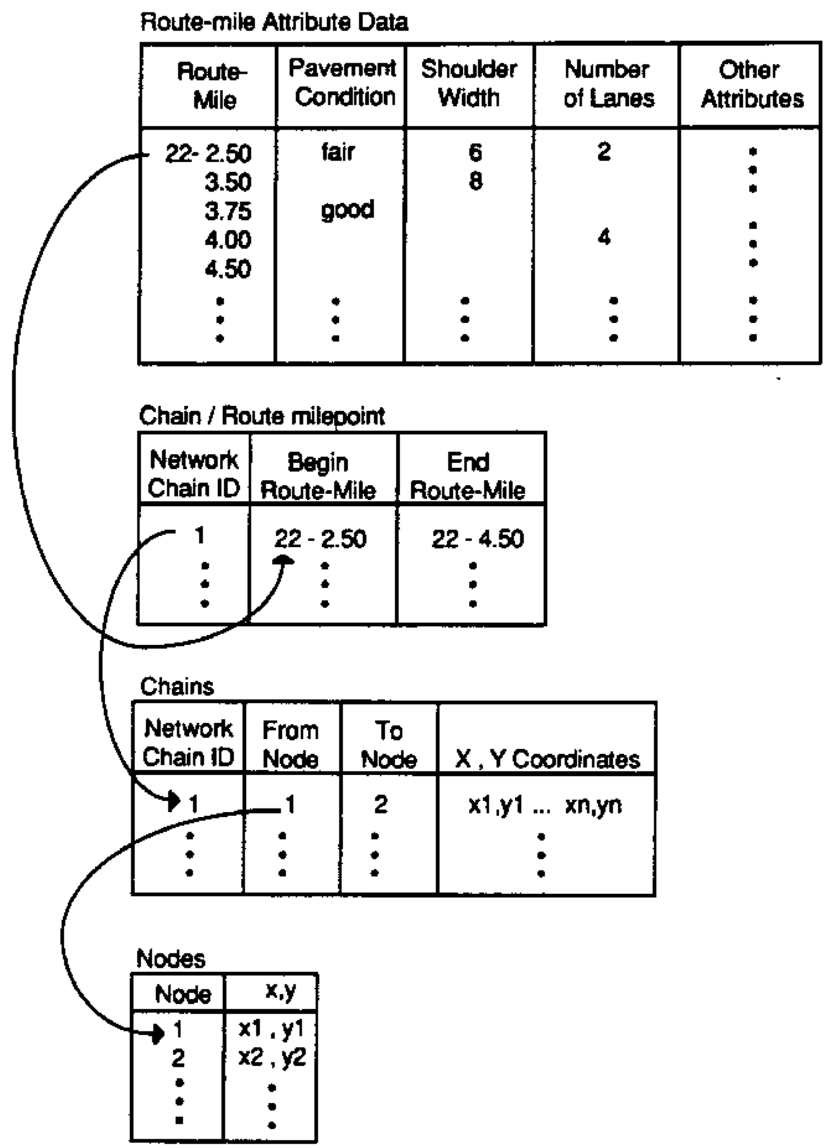


Figure 10-8: Attribute data for variable length segmentation linked to locational data.

DATA QUALITY CONSIDERATIONS IN A DATA LINKAGE

Standards for the assignment and maintenance of a data linkage should be established by group consensus and applied universally to all systems of concern. The management group for the information systems should agree on the strategy for linkage and should let users know of its potential. If records in a parcel file are to be linked to spatial data, then all records are linked in the same manner using the same linkage strategy. The fields must be uniformly formatted (or at least derivable as such) to allow for easy processing to support integration and aggregation of information. Regular use helps to ensure that the linkage will be maintained adequately. The standards to be applied include encoding accuracy, data content consistency, aggregation consistency, recording completeness, and lineage.

To ensure **encoding accuracy** a linkage code should be checked for validity against a rule for code assignment. A domain of allowable attribute codes -- e.g., integer, name, or coordinate -- should be enumerated for validity checking. The meaning of the identifier in the entity context and the formatting of the identifier in the data base object context might each require a check.

Linkage codes should maintain **data content consistency** across data records. Codes consistent across data records and files means that an appropriate code is relating data records that correspond to one another -- for example, the spatial and attribute descriptions of the same entity should be linked to one another rather than an attribute record from one entity linked to a spatial record for another.

Linkage codes must preserve an **aggregation consistency** across different levels of aggregation for the same data record/file. Having codes consistent across different levels of aggregation ensures that a general data group should be derivable from a detailed group. For example, street address ranges correspond to the range of individual addresses that can possibly be aggregated.

Recording completeness requires that all records (data objects that are representations of some real-world entity) intended to have linkages will have linkages. An estimate of the amount of abstracted reality to be represented in records/files must be made to test for completeness at the data object level. For example, all the cadastral parcels in LIS County should be included as defined by the county assessor's parcel rolls.

To track **lineage**, the derivation of the data linkage should be documented. For example, a location identifier scheme was developed by a municipality in 1969 for purposes of referencing parcels on quarter-section maps; the scheme has since been changed to reflect annexations of land to the city that took place in 1988.

ECONOMIC CONSIDERATIONS

The demand for and supply of data linkages are the product of "Who wants it?" and "Who is going to pay for it?" The best way to determine whether a data linkage is practical is to enumerate the benefits and costs associated with its implementation, or lack thereof. Determining the true benefits and costs requires a context and a set of factors to compute actual numbers. However, a general set of categories for benefits and costs can be identified, and each of them can be further specified using factors and numbers peculiar to an organization.

1. Better/more reliable information. A data linkage enhances data consistency checking that results in information with fewer errors. With better information, legal issues might be resolved before going to court. An organization can estimate the benefits of more reliable information indirectly by determining how many coding errors appear in a manually developed product.

2. Reduced duplication of effort. When data are linked to other data, need for duplicate copies of data is reduced. Multiple copies of data encourage inconsistency in data. An organization can estimate the savings in reduced duplication through a survey of the number of times information is requested internally within the organization.

3. Enhanced capabilities. Data linkages enhance the availability of data to produce information products that previously might have been too time-consuming. This can encourage more effective analysis of alternatives for the decision making process. An organization can estimate the magnitude of enhanced capabilities by examining other recently introduced information processing capabilities that enhance most applications within the organization.

4. Better service. Data linkages support faster turn-around time on projects. When turn-around is faster, personnel can provide more efficient and effective service. Gaining a more direct access to spatial data through attribute identifiers allows operation-oriented personnel to answer questions for the public in less time. An organization can estimate the benefits by enumerating how much time it takes to look up spatial information and attribute information separately.

As with other elements of MPLIS implementation, data linkages offer classical benefits.

5. Increased productivity. More projects get completed in the same amount of time or the same projects get completed in less time because data are more readily available as a result of cross reference. Computing increased productivity requires an organization to specify output relative to time and/or cost for producing that output. Information products and personnel costs are part of such a computation. An organization can determine the size of an immediate increase in productivity by enumerating the costs of manually cross-compiling information -- i.e., coding parcel boundary maps by hand with the corresponding attribute data. The benefits equal the savings in costs.

6. Problem avoidance. These are often the benefits incurred by being able to avoid problems such as confusion in information interpretation. Although this benefit is difficult to compute, certain anticipated benefits can be derived indirectly through cost avoidance.

Identifying costs of a data linkage is as important as identifying the benefits. The costs include:

1. Real costs of implementation. Both internal and external labor, software, and hardware costs should be factored into the total costs for implementation.

2. Real costs of maintenance. Organizations often fail to identify the costs of maintaining a data linkage. Over the long run, the maintenance costs can be greater than the implementation costs.

3. Risk costs. If data are corrupted, there is a risk of using the data linkage without realizing a linkage is amiss, until after information products have been delivered. The cost of lost time and lost information or misinformation should be calculated.

4. Efficiency costs. If the costs of providing the solution are greater after the implementation than before, there is a cost to efficiency. The cost of such a reversal must be considered.

5. Cost avoidance. If the data linkage is not implemented, the future costs of operation could become more significant. That possibility must be addressed.

Benefits and costs are further tempered by institutional considerations.

INSTITUTIONAL CONSIDERATIONS

Institutional considerations are broader in scope than are either technical and economic considerations. The institutional considerations stem from the socio-political, legal, and cultural context of the MPLIS. These considerations can significantly enhance and/or dramatically constrain data linkages. Some of the considerations are:

1. Expertise and availability of personnel. Only certain personnel within an organization have the expertise to implement and maintain a data linkage. Such personnel are commonly in short supply.

2. Privacy protection for sensitive information. A data linkage supports access to information. Such access must be restricted to information that is of a nonsensitive nature to protect the rights of individuals.

3. Security for unauthorized use of the linkage. Access to information through the data linkage must be restricted through security measures if the information is of a secure nature.

4. Increased coordination and cooperation. A data linkage fosters increased coordination and cooperation as long as the parts of an organization agree upon the purpose of the data linkages.

5. Attitude toward technology support. A data linkage can be deemed successful if a certain number of applications and/or users are supported.

6. Belief in better information. Better information for decision makers may lead to a more equitable and/or efficient distribution of resources described by the alternatives presented to the decision makers.

Dealing with institutional considerations sometimes requires concomitant changes in organizations. Organizational change is never easy, but the results are likely to outweigh the adverse impacts of change.

CASE STUDIES

Examples of identifiers used for data linkages are provided here as a sample of what is possible. The examples include specification of land record identifiers for counties in North Carolina, a parcel identifier for King County, Washington, and parcel and street network identifiers for Bellevue, Washington, and parcel and street network identifiers for San Bernardino County, California.

COUNTIES IN NORTH CAROLINA

The parcel identifiers for counties that receive state assistance in North Carolina are described in "Technical Specifications for Base, Cadastral and Digital Mapping" distributed by the North Carolina Land Records Management Program (North Carolina Land Records Management Program 1987). The parcel identifier number (PIN) is constructed from the North Carolina State Plane Coordinate System using the visual center of a parcel -- i.e., the centroid.

The coordinate of a centroid is measured as x (Easting) and y (Northing) -- for example, E2,715,569 and N0,756,737. The digits in each number are paired by taking each easting digit and pairing it with each northing digit:

20	77	15	56	57	63	97
EN	EN	EN	EN	EN	EN	EN

The parcel identifier is arranged in the following way:

20	7715	56	5763	97
redundant lead number for any one county	number of basic map module (1"=400')	block number	lot or parcel number	utilized only to extend the capacity of the system

The North Carolina PIN is obtained by recording the middle three sets -- the middle ten digits -- inserting dashes as follows: 7715-56-5763. The two high-order digits (20) are dropped because they are redundant "millions of feet" in State Plane Coordinates within each county. The two low-order digits (97) are dropped because, in combination, they specify such a small area. The resulting number satisfies criteria for a location identifier as long as the higher-order digits are known for each county in which the parcel is located. Records of condominiums, townhouses, or other cases of diverse ownership on one land parcel can be further identified through the use of decimal digits (from 001 to 999) appended to the right of the PIN. Thus, 7715-56-5763.008 would signify unit number 8 within this land parcel.

Since a PIN is a location identifier based on the SPCS, the identifiers for finer resolution diverse ownership are difficult to create within the same location framework. Condominiums often are high-rise buildings, necessitating a third spatial dimension in the location problem. The third spatial dimension is not part of the State Plane Coordinate System. An enhancement to the location identifier outside the state plane framework is often used as a compromise between identifier simplicity and location system complexity. The decimal digits indicating diverse ownership add to PIN complexity, but not to the extent that a location specification would. The size of the decimal field, i.e. three digits, allows for a maximum of 999 units. In most cases this would be sufficient; however, it could be set higher if needed. The use of a "decimal point" to indicate the extended identifier rather than using a "dash," as in the other portion of the identifier, is a matter of design. The difficulty with a decimal identifier involves mixed-mode processing for software. However, this is a computer programming issue and not an information content issue. In either case, the simplicity of the identifier outweighs the data processing inconvenience.

KING COUNTY, WASHINGTON

The King County tax account number used as a parcel identifier contains 12 digits : XXXXXX-XXXX-XX (King County 1990). In the identifier:

- The first six digits compose the major number,
- the next four digits compose the minor number,
- the next to the last digit is the split code, and
- the last digit is a check digit for data processing.

The "major number" is a combination of "section, township, range" or is an "integer number" depending on whether the parcel is unplatted or platted, respectively. The "minor number" is a "government lot number" or a "sequence number" depending on whether the parcel is unplatted or platted, respectively. (The terms "major" and "minor" indicate significance of coded number, and have no other interpretation.) Thus, if the land is an unplatted parcel, the code takes the form:

SSTTRR-9LLL

where:

SS is the section number
TT is the township number
RR is the range number
LLL is the lot number

If the land is an platted parcel, the code takes the form:

PPPPPP-#NNN

where:

PPPPPP is the plat number assigned by the Assessor's office
is a number from 0 to 8
NNN is the sequence number assigned by the Assessor's office.

The eleventh digit (split code) has accounting uses but does not identify a distinct parcel of land. For either platted or unplatted parcels, the split code is interpreted as:

0: The parcel has undergone no boundary or tax changes since the first of the current year.

3-6: The parcel has had one or more boundary or tax changes since the first of the current calendar year.

8,9: The 11-digit parcel number represents a separate billing account (not a separate parcel), created for one of several possible reasons:

- Land and buildings are owned by different entities,
- some portion of the property is subject to an exemption,

- such as a senior citizen's or church/non-profit exemption, or
- a separate tax bill is needed to collect back taxes and interest for a parcel removed from "open space" classification.

If the land is in state or public service, the major number appears as 97XXXX, where XXXX is a code for the type of service, -- for instance, a service parcel for transportation is 970XXX.

The complexity of an identifier results from the amount of information included in the identifier. Although the parcel identifier in King County may seem complex for those outside the county, the identifier must be based on local needs. Different local governments will have different interpretations of their needs.

CITY OF BELLEVUE, WASHINGTON

Two types of data in Bellevue that require linkages for many applications are parcel and roadway data (Burt 1990). Other data such as water/sewer or subareas are usually managed as a single unit so no data linkage identifiers are necessary.

The City of Bellevue has historically maintained two parcel identifiers for its parcels. It uses the King County Assessor's parcel number (as described in Sect. 10.5.2) for tracking lots. However, the lot number is stored as an annotation item rather than as a data base item. The difference between an annotation item and a data base item is that the annotation item cannot be searched, sorted, or otherwise processed as can the data base item. The assessor number is used to relate parcel location with tax information, which is received from the county on a quarterly basis.

The city also maintains a "map and parcel" number (of the form XXX-XXX) generated in the city for internal maintenance of the Storm Drainage Billing System. The "map" portion of the number is an integer identification ID based on counting the 269 quarter-section maps, with ID's ranging from 2 to 270. The "parcel" portion of the number is a sequentially increasing integer assigned at random within the confines of each map, with 3 digits assuming no more than 999. The two numbers are often "redefined" as a concatenated data linkage -- i.e., combined as

XXXXXX -- to add flexibility for data references. The single number can then be used for data referencing.

Since many assessor parcel numbers may correspond to one quarter-section map, a cross-reference index is used to determine the association between assessor parcel numbers and map parcels. The cross-reference is essentially a digital table look-up that associates the assessor parcel number with each map and parcel number for Bellevue. In addition to the assessor parcels, every map and parcel number is associated with a single site address. Site addresses are assigned from an address range scheme originating from the county, but locally maintained in the city at the time of this writing. Several applications exist that make use of the site address reference.

Several roadway data bases exist in the city for various transportation engineering, management, and planning purposes. All data bases use either a pavement ID or node ID form of identifier. Pavement IDs are assigned to sections of roadway, many of which exist between two intersections. The node ID is for places of network change, mostly at intersections. Accidents and traffic counts have been linked through the pavement ID. All new systems requiring reference to pavement information will use the pavement and node IDs.

The parcel numbering schemes have been in place for a long time and are well accepted by users because they have been effective. The pavement ID and node ID schemes are relatively new, and all users are still exploring their uses. More applications showing the effectiveness of the pavement/node data linkages are being planned.

SAN BERNARDINO COUNTY, CALIFORNIA

San Bernardino County, California, has embarked upon an ambitious $12 million multi-agency GIS project, part of which is to develop a digital basemap that will reference 650,000 parcels over a 20,000-square-mile area of southern California. Planned users of the system include county agencies, municipalities, utility companies, private sector interests, and private citizens. Developers of the system state that a key factor in the success of the multi-user system is the design and content of the basemap. The County has given a high priority to the integration of existing tabular (attribute) data within their GIS. Many geographically oriented data bases are used by the County, cities, and utilities.

It is essential that the GIS easily accommodate the linkage of existing tabular data.

The County basemap provides a framework for spatially referencing tabular data. The basemap consists minimally of survey control, tax parcels, and street rights-of-way. The two essential identifiers that will best facilitate the linkage of attribute data to the basemap are the assessor's parcel number and the situs address for each parcel.

The Assessor Parcel Number (APN) provides the means for linking several important property data bases. The APN is composed of the assessor's "Book, Page, Block, and Parcel Number" to form a unique identifier for every assessment parcel. The Book, Page, and Block are functions of the parcels' location in the assessor's map atlas. The Parcel Number must be unique for each Block but otherwise can be arbitrarily assigned. The APN is a 9-place integer field that breaks down as follows:

Column	Item
1 - 9	APN
1 - 4	Book
5 - 6	Page
5 - 7	Block
8 - 9	Parcel Number

The assessor maintains the Property Information Management System (PIMS), which stores property ownership, characteristics, assessment, and history data. These data are frequently linked to the GIS for mapping and analysis purposes. Other data such as building permit and weed abatement records are indexed by APN to facilitate linkage to PIMS and the GIS basemap.

Property documents of record such as deeds, subdivision plats, and record of surveys are referenced during property transactions or when development occurs. Managing these documents as scanned images is being evaluated by the County. If linked to the GIS base map by APN, automated spatial access to record documents could be supported.

Situs (street) addresses are an important part of the location referencing capability in the San Bernardino GIS basemap because of the large number of local government organizations that use it. The address of a structure or the address of an applicant is requested for nearly every permit, complaint, property transfer, request, infrastructure work order, or other such document. Street addresses for improved land parcels as well as address ranges to locate unimproved parcels is to be included in the basemap reference system design. In addition, street addresses are to be used as a link between intersections and related information -- e.g., traffic accidents and traffic signals -- as well as between facility records and rights-of-way through the street name reference.

Several indirect linkages to tabular attribute data bases are to be supported. Subdivision tract and lot numbers link through the PIMS, which contains APNs. Public Land Survey System (PLSS) references in attribute data bases are to be supported through a data layer of PLSS boundaries. Transportation data concerning traffic citations, pavement and facility management, and accidents are to be indirectly linked to the GIS through a street-name and milepost or route-name and milepost (Nyerges 1990) reference. Instead of street address, the milepost number locates events along the street.

Most of these issues are included in a conceptual design that enhances the current GIS capabilities of San Bernardino County. A prototype implementation of the conceptual design is being completed in the Spring of 1991 (Gooch 1990).

CONCLUSION

Identification of certain land information entities is so significant that special codes are created for that purpose. Those same codes can be used for linking data groups. Although a unique code provides a means for linking each land information entity to various data registers, it does not provide a link to all land files. A spatial reference system such as state plane oordinates or Universal Transverse Mercator, supported by a geodetic control system, should be used for special-purpose geographic integration of land data files across different coverages by virtue of the geographic position in the coordinate system. That integration is called data layer overlay and is discussed in Chapter-11.

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GLOSSARY

attribute: a quality or quantity describing an entity (National Institute of Standards and Technology 1990).

computer-aided mapping system: a system that focuses on map design, creation, and maintenance (Dueker and Kjerne 1989).

data group: a collection of data that has a special meaning and is commonly stored together. The term here substitutes for other implementation-bound constructs such as records and files.

data linkage: an association between/among data which enhances the effectiveness and/or efficiency of information processing; a reference from one set of data to another that allows access across data. For example, spatial data records and the corresponding thematic attribute data records can be linked for cross-retrieval to support display and/or analysis.

entity: a real-world phenomenon not subdividable into phenomena of the same kind (National Institute of Standards and Technology 1990)

geocoding: the assignment of geographic codes to records, can be manual or automated (Huxhold 1991).

geographic code (geocode): 1) A data value, assigned to a spatial object, that provides information on the geographic location of the object and is used as a key to access data relating to the object (Dueker and Kjerne 1989). 2) An identifier assigned to both a map feature and a data record containing attributes that describe the entity represented by the map feature. Common geocodes include addresses, census tract (numbers), and political and administrative district (numbers). Geocodes are also referred to as "location identifiers" (Huxhold 1991).

geoprocessing: expanding geocodes to reference other features at the same location (Huxhold 1991).

geographic information system (GIS): 1) A system of hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the Earth (Dueker and Kjerne 1989). 2) A computerized data base system for capturing, storing, retrieving, analyzing, and displaying spatial data. (National Science Foundation 1987)

identifier: a label that uniquely identifies a cartographic record and resides in the nongraphic record(s) for data linkage purposes (Huxhold 1991).

key: a data item used to identify or locate a record in a data file (Huxhold 1991). primary key: a key used for principal access to a unique record. secondary key: a key used as an alternative to the primary key for access to one or more records. foreign key: a primary key used to address from one data group into another data group.

land information system: a geographic information system having, as its main focus, data concerning land records (Dueker and Kjerne 1989).

location identifier: a unique code (number or combination of letters and numbers) used as a record identifier in a (nongraphic) attribute data base, and representing a unique feature (entity) that can be identified on a map (Huxhold 1991).

MPC (multipurpose cadastre): a parcel-based land information system (Dueker and Kjerne 1989).

MPLIS (multipurpose land information system): a land information system that serves two or more departments or organizations (commonly) in local government.

nongraphic data: attributes of cartographic entities needed to describe the physical characteristics of entities in the real world (Huxhold 1991).

object: a digital representation of an entity (National Institute of Standards and Technology 1990).

parcel identifier: a code for recognizing, selecting, identifying, and arranging information to facilitate organized storage and retrieval of parcel records (National Research Council 1983).

11 IMPROVED ANALYTICAL FUNCTIONALITY: MODERNIZING LAND ADMINISTRATION, PLANNING, MANAGEMENT, AND POLICY ANALYSIS

Bernard J. Niemann, Jr.

INTRODUCTION

Modern land and geographical information systems (GIS/LIS), which couple land records with improved spatial analysis, offer new opportunities for more efficient, effective, and equitable land administration, planning, management, and policy analysis. When spatial analysis capabilities such as topological overlay are also included in the GIS/LIS, management, planning, and policy analysis techniques can be used to address such issues as land-use planning, soil-erosion assessment, and water-quality estimation models. This coupling of information technology and spatial analysis offers land management professionals visualization and analytical tools much more powerful than any before. This chapter looks at examples of functions and applications, and the benefits deriving from use of GIS/LIS functions, and identifies the potential problems that errors can bring to the outcome of these analyses.

HISTORICAL CONTEXT

Public responsibility for the long-term and efficient administration, planning, management, and policy analysis of land use, its resources, and its tenure has roots reaching back to the founding of the republic. To a large extent, this process of land information management has, from a mechanical land records perspective, changed little in the past two hundred years.

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The mechanical process of using land information spatially has been primarily a manual process. Complex analyses of spatial information are attempted only on an occasional basis as a situation merits the extra social and economic investment. The use of information technology historically has been limited primarily to applications related to improving measures of efficiency.

Modern land and geographic information technology offers the opportunity to unbridle the restraints of overly burdensome procedures through improved analytical functionalities. By "improved functionality" we mean the ability to manipulate, analyze, and display spatial information through the use of automated rather than manual procedures, or the ability to manage and manipulate cartographic and geographic (spatial) data. Much of this capability lies in the analytical "operators" that provide new and creative opportunities for the land administrator, planner, manager, and analyst. Even though these operators are in their infancy, the potential analytical power is awesome compared to past manual techniques and procedures.

Land information administrators, planners, managers, and policy analysts have historically called for a comprehensive and integrated approach to land information management. These groups have had a major influence on the collection of information to address both urban and rural land planning and management.

As far back as the nineteenth century, coordinated planning of human actions and environment was called for by the likes of Patrick Geddes, George Perkins Marsh, and John Wesley Powell. Around the turn of the century, major contributions to this concept of integrated land conservation and open-space planning were made by Jens Jensen and Frederick Law Olmstead, and their land planning contemporaries. In a recently reprinted work, Geddes (1968) advocated the use of regional inventories of soil, rainfall, climate, land use, and land tenure relationships to integrate people with place.

The most succinct early understanding of the need for an integrated set of land information inventories and for developing a connection of people with place came from Warren Manning (1909), a Boston-based land planner, who wrote:

> "What we want is a general survey covering all this territory [New England], upon which the character of the soil, the subsurface water conditions...the character of the ground

cover, the age and condition of the forest plots, the boundaries of existing land holdings, and all other data [can be collected]...in order that we may know best how to develop each resource."

Parallel with these calls for inventories and integrated land information-based approaches, new visualization and spatial analytical techniques were also developed. Overlay -- one such method for land planning, management, and analysis -- is an example. Manning is credited with "...the invention of the overlay technique for integrating natural and cultural information" (Steinitz et al. 1976), which Manning documented in his 1913 Town Plan of Billerica, Massachusetts (Manning 1913). Overlay, as a spatial operation, remains a fundamental tool for planning and a primary form of spatial thinking in land planning, management, and analysis. However, as Steiner et al. (1988) point out, overlay as a spatial thinking concept can now be augmented by "...more sophisticated and powerful computer-based approaches" such as GIS/LIS.

Because of the historical technical difficulty in accounting for physical land characteristics, the human condition, and legal interests in land, the translation of Manning's conceptual ideas of information-based land administration, planning, management, and analysis has proven to be more difficult than anticipated. Demonstrated successes in integrated land planning have been few, especially in those areas where land planning is most common, "... namely in established cities and in the counties of the United States" (Steiner et al. 1988). Steiner's group also points out, historically, that land planning and management have seldom succeeded at the level of the individual's environment. This is especially unfortunate in light of his observation that "... [planners', managers', and land administrators'] ordering of the human environment may ultimately determine how successfully individuals are accommodated into the environment" (Steiner et al. 1988). Planners, managers, administrators, and analysts share the same problem: moving from micro-analysis at the individual level to a macro-understanding of the overall consequence of a set of individual actions formulated by tradition, mandates, and public policy.

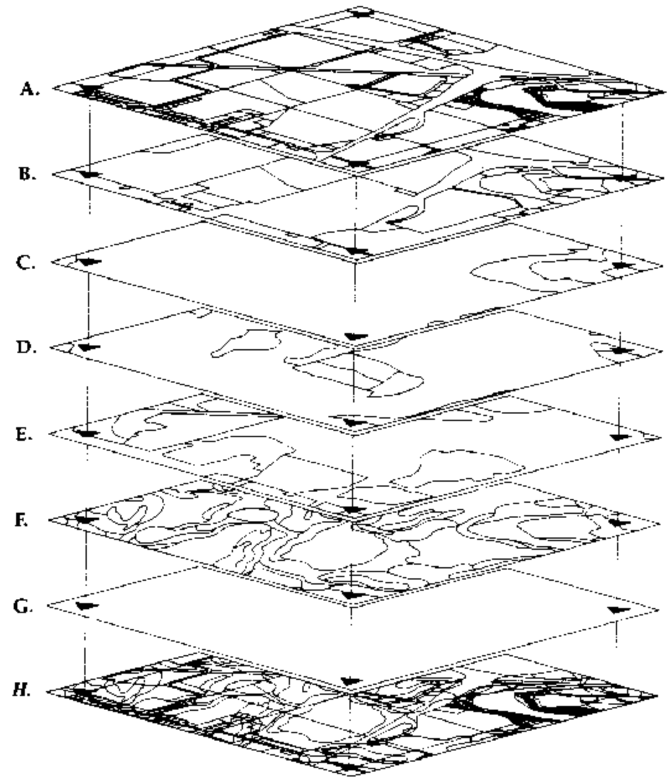
Understanding the cumulative environmental, social, and economic impacts of individual actions requires an assimilation of individual aspirations, plans, and outcomes. Subsequently, societal goals based on this understanding must be translated back to mechanisms for individual participation through laws and plans. By incorporating Manning's concepts with modern information technologies and more powerful analytical functionality, it is now possible to conduct comprehensive land information inventories and analysis consistently over large land areas in a multipurpose land information system (MPLIS) (Figure 11-1). The concept of MPLIS can be used for land planning, based upon the integration of various separate functions. The concept requires the automation of various resource layers such as soils, land cover, etc., but it also explicitly requires the automation of the land ownership layer and the modernization of the Public Land Survey System (PLSS) and the National Geodetic Reference System (NGRS) to establish a mathematical reference system (Niemann et al. 1987).

LAND INFORMATION MANAGEMENT RESPONSIBILITIES

The management of land information and associated records can be divided into four general types of responsibilities. These are those responsible for administration -- the collectors and processors of land information such as register of deeds, county surveyor, county clerk, tax assessor, data processing manager, etc.; those responsible for the use of this land information for planning -- such as the land use planner, engineer, and tax assessor; those responsible for land information management -- such as the water utility, parks department, and land conservationist; and those responsible for policy analysis and determination -- such as the county board, city supervisor, county executive, and others.

Because none of these types of land information management responsibilities is distinct, overlap is considerable. Each responsibility, however, requires different types and levels of land information and different techniques to address each entity's responsibility. These differences also require different types of analytical or spatial operator functionality. For example, those responsible for land information administration require data bases and data base management techniques that are more detailed than those for policy analysis. In contrast, those with policy analysis responsibilities require more complex analytical functionality to derive their informational needs (Figure 11-2).

If mandates for the care of the nation's resources are to have any effect, citizens and elected officials must have access to the information available regarding proposed actions. MPLIS technology, along with relevant analytical functionality and with



Concept for a Multipurpose Land Information System

Section 22, T8N, R9E, Town of Westport, Dane County, Wisconsin

Data Layers:	Responsible Agency:
A. Parcels	Surveyor, Dane County Land Regulation and Records Department.
B. Zoning	Zoning Administrator, Dane County Land Regulation and Records Department.
C. Floodplains	Zoning Administrator, Dane County Land Regulation and Records Department.
D. Wetlands	Wisconsin Department of Natural Resources.
E. Land Cover	Dane County Land Conservation Committee.
F. Soils	United States Department of Agriculture, Soil Conservation Service.
G. Reference Framework	Public Land Survey System corners with geodetic coordinates.
H. Composite Overlay	*Layers integrated as needed, example shows parcels, soils and reference framework.*

Land Information and Computer Graphics Facility,
College of Agricultural and Life Sciences, School of Natural Resources
UNIVERSITY OF WISCONSIN-MADISON

Support provided by the Gordon H. Barker Fund of the University of Wisconsin Foundation.

Figure 11-1: Concept diagram: a multipurpose land information system

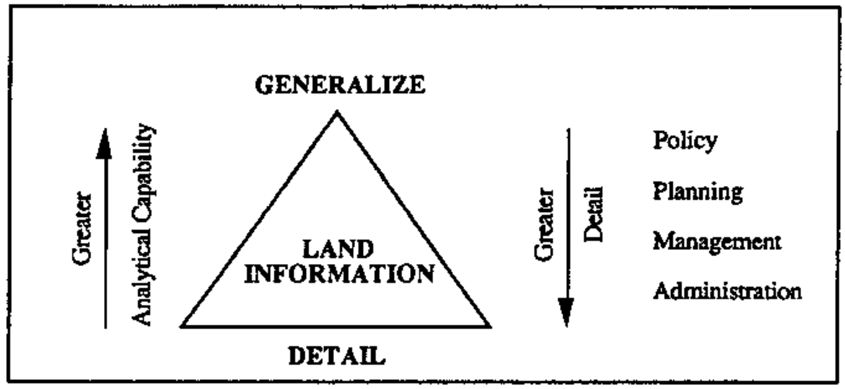


Figure 11-2: Policy analysis responsibilities require more complex analytical functionality than do other responsibilities. (from Huxhold 1991; Niemann and McCarthy 1979)

mathematical models simulating the land-use scenarios, as called for by Steiner (1989), can prove its worth in helping to predict human impact on the land. From such a data base of land information variables, people can work together to assess the alternatives, to consider the implications of development, and to make choices from clearly defined options.

ECONOMIC, ENVIRONMENTAL, AND LEGISLATIVE CONTEXT

Before we begin to explore the breadth of spatial functions now available, it is important to understand the potential impact of spatial information technology on land administration, planning, management, and policy analysis in general. Technology associated with GIS/LIS, land records modernization, automated mapping and facilities management (AM/FM) systems, infrastructure management, etc. has spawned booming U.S. and Canadian industries. Estimates vary, but most are compelling. In 1989, Dataquest, a San Jose, California, computer-marketing company, estimated the software/hardware portion of this spatial information industry in North America would be $600 million annually by 1992. In 1991, Market Intelligence Research Corp. of Mountain View, California, projected higher estimates world-wide -- up to $27 billion by 1997.

Similarly, GIS/LIS expenditures at the Federal level have also been expected to increase significantly. The U.S. Office of Management and Budget (OMB) estimated in 1989 that, by 1992, the expenditure in "electronic mapping data bases" alone would amount to $200 million annually (not including national security expenditures) (Arthur 1989). The U.S. Environmental Protection Agency (EPA) has planned to invest over $50 million in spatial information technology and impose automated geographic locational requirements on those responsible for reporting environmental conditions to EPA (GIS World 1989). The U.S. Department of Agriculture (USDA) Forest Service has said that it intended to invest about $922 million in the next 12 years to purchase GIS hardware and software to support resource management systems for all National Forests (Smith 1992). The U.S. Department of the Interior (USDI) Bureau of Land Management (BLM) has planned to employ land information systems to manage resources, maintain all the legal records associated with the PLSS, and maintain mineral rights records for all Federal lands (USDI BLM 1989). Other Federal agencies such as the USDA Soil Conservation Service have also planned major commitments to GIS technology (Liston and TeSelle 1988).

There are compelling reasons for this technological boom in land administration, planning, management, and analysis. Public, legislative, and congressional accountability for monetary investments in land planning and management are beginning to drive local, state, and Federal agencies toward the incorporation and use of GIS/LIS technology. Wisconsin citizens spend about $140 million annually to collect and administer information about land, its owners, and its value (WLRC 1987); this amounts to about $30 per resident annually. This expenditure is made with little understanding of the overall environmental, social, or economic consequences of this investment. The administrative and managerial requirements associated with this massive and continuing land records investment have become complex, requiring more efficient and effective methods. GIS/LIS tools have demonstrated order-of-magnitude shifts in increased efficiency (Chrisman et al. 1986). The State of Wisconsin, in an example of mandating individual landowner accountability, created a program to reduce soil loss (Chapter 92 of Wisconsin State Statutes 1981). The resulting administrative rule (Ag 160) states that:

> "Each [county] land conservation committee shall prepare a soil erosion control plan which does the following: ...

2. identifies the parcels *(people)* and locations of parcels *(place)* where soil erosion standards are not being met [92.10(5)a] (italicized words added for emphasis)."

In 1985, to further strengthen this public goal of soil erosion control, the Legislature created a "cross-compliance" provision between soil erosion control plans (place) and a farmer's access to farmland preservation income tax credits (people). This mandate of linking "the carrots of tax incentives with the sticks of regulation (public policy) offers a powerful tool (economic and legal)" to the land administrator, planner, and manager (Sullivan et al. 1985).

Nor did cross-compliance as a technique to implement public policy concerning conservation go unnoticed at the Federal level. The 1985 Food Security Act (FSA) and the conservation title (XIV) of the 1990 Food, Agriculture, Conservation, and Trade Act (FACTA) include mandates for the restriction of tillage of marginal and highly erodible lands, incentives for the restoration of wetlands into the Wetlands Reserve Program, expansion of the conservation reserve program (CRP) into the environmental easement, and directives about non-point and groundwater quality management as part of the Agriculture Water Quality Protection Program. To gain access to Federal farm commodity program benefits, compliance with various conservation restrictions is required.

According to Steiner (1989), the 1985 congressional mandate is "the most sweeping federal land use legislation for privately held U.S. farmland since the Homestead Act of 1862 ..." He points out that these farm-level conservation plans are:

> "... essentially physical land use plans for farms. The plans require that each landowner or manager be identified, the cropping history of each field, a resource inventory and analysis of each farm, as well as an identification of soil types, wetland condition and erosion and drainage problems at present. This information is all mapped onto aerial photographs manually at the local level. By assimilating the various factors by applying overlay-analysis, a management agreement between the land owner and the public, a map is prepared that outlines appropriate uses for each acre of the farm ..."

This overall land information and integration process is not at all unfamiliar to those trained as land administrators, planners, and managers. The process of data collection and organization focuses upon the individual farm property and field as the most fundamental land management unit. This process of determining appropriate uses for each acre is quite similar to Manning's (1909) message that knowledge about the land and its owners was essential "...in order that we know best how to develop each resource." In essence, Manning was calling for a modern multipurpose land information system, for it represented the comprehensive and integrated approach to resource management problems. What Manning could not foresee was the invention of the computer and the incorporation of spatial analysis capability such as overlay analysis. Spatial computing now provides the opportunity to implement his vision. Local, state, and Federal resource management mandates might ensure its realization.

SYSTEM FUNCTIONALITY

Software technologies associated with modern GIS/LIS are undergoing rapid change. Spatial display and analysis functions are also undergoing change, from automated forms of data retrieval, structuring and transforming, or expanding capability to automated forms of analyses in overlay, network, or matching of data. As a result, a common and agreed-upon conceptual framework and taxonomy for the various analytical spatial operator functions that are integral to an overall information system have not yet been formulated. Past attempts to clarify analytical functions are all that is available to assist those who must recommend and choose between the available alternatives. The array of spatial analytical functions in GIS/LIS software can be better understood if they are presented as five conceptual organizational schemes. Combinations of these illustrate various uses of the overall functions.

As GIS/LIS technology has matured, so has a rich and varied set of functional cartographic and spatial data handling and manipulation procedures. These operators are not to be thought of as spatial analytical functions in a traditional statistical sense, for most known statistical techniques are based on the premise of data being observed independently. Geographical data tends to have spatial dependency and this "spatial autocorrelation" invalidates most existing statistical procedures (Openshaw 1990). In this discussion, "system functionality" refers to those analytical capabilities associated with the management and manipulation of cartographic and spatial data.

EMPIRICAL MODEL

The first organizational scheme is essentially an empirical one, resulting from the study of governmental agencies such as municipalities. These studies have identified two sets of generic tasks -- procedural (e.g., administrative) and managerial (e.g., planning and management) -- associated with municipal functions (Dangermond and Freedman 1984) (Table 11-1).

Procedural Tasks	Managerial Tasks
Acquiring and disposing of property	Creating and managing mailing lists
Processing and issuing parcel-related permits	Allocating human resources
Performing inspections	Responding to public inquiries
Providing legal notification	Managing facilities
Issuing licenses	Managing inventory
Naming streets	Managing resources
Reviewing site plans	Controlling weeds
Reviewing subdivisions	Managing mapmaking
Creating street addresses	Managing drawing/drafting
Reporting events	Managing data bases
Dispatching vehicles	Tracking development
Routing vehicles	Disseminating public information
Analyzing traffic	
Siting facilities	
Administering area distributing	
Administering zoning by-laws	
Conducting land-use planning	
Conducting engineering design	
Conducting drafting	
Searching titles	
Performing tax/fee billing collection	

Table 11-1: Observed Generic Municipal Tasks

To respond to this basic generic set of municipal tasks, ten data or land record components were identified to support these analysis queries associated with each task (adapted from Dangermond and Freeman 1984). These components were:

1. Base map consisting of control data and topography.

2. Environmental overlays such as water, soil, geology, etc.

3. Engineering overlays such as the locations of roads, sewers, etc.

4. Plan/Profile drawings of such infrastructure elements as sewers and water lines.

5. Parcel maps that delineate land ownership boundaries of all public and private lands.

6. Parcel/Street address tabular data that describe characteristics about the owner of a parcel or about the parcel itself such as tax billing, building permits, etc.

7. Area tabular data that describe characteristics about block or districts such as the character of school districts.

8. Street tabular data that include a variety of data associated with the street such as address range, pavement condition, etc.

9. Street network file such as topological network.

10. Area boundary maps such as data bases that define city blocks, school districts, census tracts, and zip code boundaries. These maps correspond to the attribute data previously listed.

To address the various tasks using these components, five basic sets of analytical functions (adapted from Dangermond and Freeman 1984) were used to support the various applications:

1. *Graphic overlay*: The overlaying of various data layers or records upon each other graphically. This function allows for spatially interrelating such land record items as parcel boundaries with utility locations.

2. *Topological overlay*: The overlaying of various data layers or records by joining the geographic elements. This function provides for interrelating such land records as parcel boundary and ownership with poor soil sewerability boundaries resulting in a new data layer of parcels not appropriate for on-site waste disposal. This new characteristic of the parcel becomes part of the attribute data base about each parcel.

3. *Address geocoding*: A spatial matching procedure whereby the street address can be assigned to street segments or networks. This function provides for interrelating such tabular or attribute land records as owner's name and address with the graphical portrayal of the street segment.

4. *Polygonization*: The spatial analytical procedure of dissolving line segments between similar polygons. This function provides for interrelating such land records as parcel boundaries into a new and larger polygon such as an administrative unit (e.g., a school district or land-use zoning district) by aggregating parcel boundaries of similar zoning.

5. *Relational matching*: An analytical procedure used to relate tabular data to spatial data. This function, now supported by a variety of relational data base vendors, is used, for example, to connect such land records as owner's name from the tax assessment relational data base with the ownership polygon from the graphic file. The name can actually be displayed within the boundaries.

HIERARCHICAL MODEL

The second organizational scheme is that proposed by Burrough (1986): a hierarchy of data transformations for geographical information systems. Figure 11-3 conceptualizes how various system capabilities can be used for spatial data utilization and analysis. Functions for utilization and analysis are divided into those operations that deal with the topology or spatial aspects of data, those that act on the non-spatial attributes, and those that work on both.

- TRANSFORMATION
  - MAINTENANCE
    - Editing
    - Updating
  - UTILIZATION AND ANALYSIS
    - Topology
      - Rotation, translation
      - Scale transformation, stretch
      - 3-D Display
      - Area, perimeter calculation
    - Properties
      - Retrieval
      - Logical/mathematical analysis
      - reclassification
        - Univariate/hierarchical
        - Multivariate/statistical
    - Topology + properties
      - Retrieval
      - Overlay and intersection
      - 'Region' analysis
      - Neighborhood analysis
        - Spreading
        - Detecting shape, narrowness, etc.
        - Interpolation
          - 'Deterministic'
            - BSplines
            - Thiessen polygons
            - Contours by
            - Inverse distance weighting
          - Statistical'
            - Trend surfaces
            - Autocovariance analysis
            - Kriging, etc

Figure 11-3: Hierarchy of data transformation operations.

Burrough (1986) proposed a general model for data analysis (Figure 11-4) where the link is the data analysis function -- any set of operations that convert one or more input maps into an output map. These analytical capabilities vary from simple data retrieval

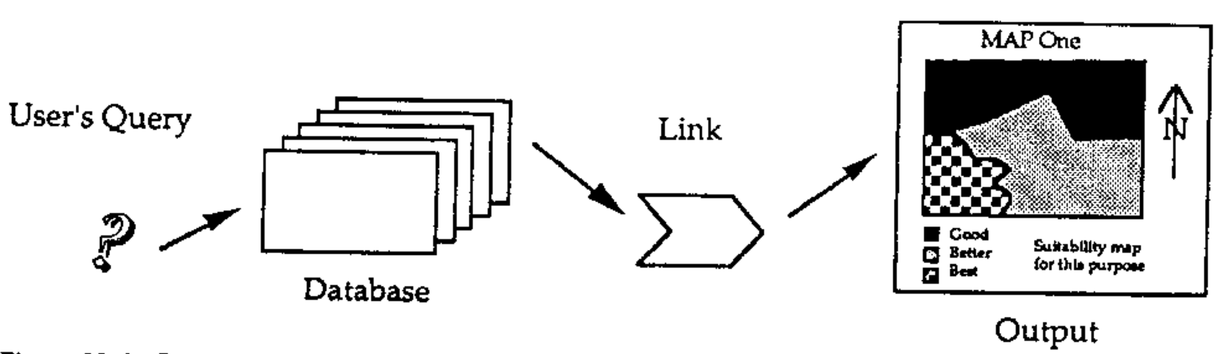


Figure 11-4: Data analysis problem.

and display functions, such as land ownership parcel boundaries merged with distances to shopping opportunities, to complex analytical tasks, such as network analysis for optimum fire truck routing. Burrough proposed an array of operators (Table 11-2).

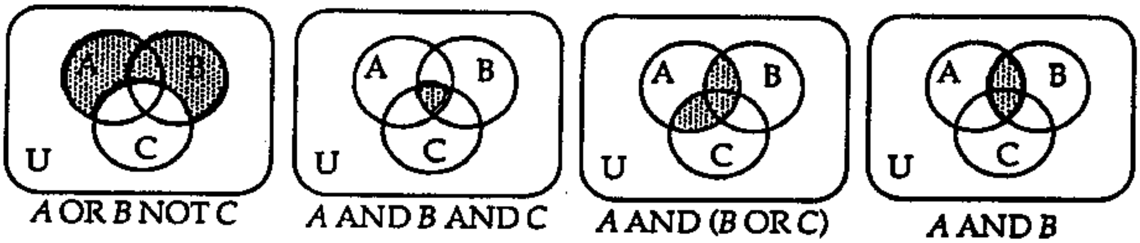
Operators	Example/Description
Simple data retrieval functionality	
Boolean logic	--Show all parcels with commercial <u>or</u> industrial zoning
Reclassify and display	--Show adjacent parcels with same owner as one parcel
Boolean operation on 2 or more maps	--Display all wetlands <u>and</u> greenspace
Map overlay functions	
Point operations (raster)	--Functions of attributes at one locus. Add attributes from Maps A and B to create Map C.
Region operations	--Properties of a region containing a locus. Give size of region A.
Neighborhood operations	--Associations of a locus with its neighbors. Show all areas visible from Point p.
Cartographic modeling functionality	
Arithmetic processes	--Adding, subtracting, multiplying maps
Logical processes	--Renumbering, clustering, reselecting portions of a map
Linking operation processes	--Combine a set of commands in a selected order to produce output

Table 11-2: Function operators (adapted from Burrough 1986).

Although Burrough concentrated on raster data structure functions, the scheme works for vector functions as well. Simple data retrieval procedures in a vector-based, layer system are straightforward. Parcel line boundaries can be displayed as the result of a simple call to the data base. The use of Boolean logic allows additional capability, using AND, OR, and XOR operators on attributes of the data elements. Venn diagrams (Figure 11-5) help visualize Boolean logic.

GOODCHILD MODEL

The third scheme is that provided by Goodchild (1989), which outlines a data model (Table 11-3) in which Type = point, line, area; Object = individual elements of a type; Class = category of each type, with attributes. In his scheme of GIS



	PARCEL-ID	AREA	ZONING	VALUE	BUILDINGS
*	5041	12,000	C	$ 92,050	0
	5633	3,541	R	$ 19,233	0
*	2346	23,442	C	$ 18,335	1
	9743	18,276	C	$119,000	2

Figure 11-5: Venn diagrams of Boolean sets.

	Type		
	Line	Point	Area
Class	road stream boundary	well windmill gauging station	lake wetland parcel

Table 11-3: Structure of a data model (Goodchild 1989).

functionality, Goodchild (1989) presents two levels of analytical operators: Level 1 spatial analysis operators are classified as performing one or more of the following functions:

a) Attribute analysis of a single class of objects (statistical analysis);

b) Locational and attribute analysis by a single class of objects;

c) Attribute analysis of object-pairs;

d) Analysis of more than one class of objects;

e) Creation of new object-pairs for one or two existing classes of objects; or

f) Creation of a new class of objects from one or more existing classes of objects.

Level 2 classifies the types of objects being processed. Creating an area from a line is different from creating an area from a point, though both are group (f) operations. Using this kind of classification framework, a comparison can be made between the function of the operator (i.e., a-f) and the type of operator (Table 11-4).

	Analysis Function					
Type of Operator	(a) Attribute analysis by a single class	(b) Locational & attribute analysis by a single class	(c) Attribute analysis of object pairs	(d) Analysis of more than one class of objects	(e) Creation of new object pairs for one or more existing classes of objects	(f) Creation of new class of objects from one or more existing classes of objects
Boolean selection	X					
Nearest neighbor analysis		X	X			
Spatial autocorrelation		X	X	X		
Thiessen polygons					X	X
Spatial interaction modelling				X	X	X
Transport network analyses:				X		
--Shortest path analysis		X	X	X		
--Optimum tour routing		X		X		
--Location-Allocation		X	X	X		
--Transportation and transhipment problem		X				
Polygon overlay						
--New area objects					X	X
--New point objects				X		X
--New line objects				X		X
--New attributes				X		

Table 11-4: Analysis functions by operator.

GIS WORLD, INC., MODEL

The fourth organizational scheme is that provided by GIS World, Inc. (1990). The results of a survey returned by 100 vendors were published as an indication of the state of software functionality (Table 11-5). This survey has also been conducted

- Measurements
  - Straight distance
  - Curved distance
  - Proximity analysis
  - Area measurements
- Buffer generation
  - Around points
  - Around polygons
  - Along straight lines
  - Curved lines
  - Weighted
- Map algebraic functions
  - Add/Subtract maps
  - Mult/Divide maps
  - Exponential maps
  - Trigometric functions
  - Differentiate values
- Polygon operations
  - Polygon overlay
  - Point in polygon
  - Line in polygon
  - Merge/Dissolve
  - Delete spurious polygons overlay
  - Thiessen polygon generation
- Terrain analysis with TIN and DEM data
  - Compute slope angle
  - Determine compass aspect
  - Interpolate elevation
  - Line of sight viewshed
  - Generate elevation contours
  - Model drainage network
  - Generate terrain cross-sections
  - Cut/Fill calculations
- Miscellaneous
  - Analysis within corridor
  - Boolean operations multiple maps
  - Boolean operations multiple themes
  - Nearest neighbor search
  - Computer optimal path
  - Compute weighted optimal path
  - COGO operations
  - Network analysis
  - Vector to raster conversion
  - Raster to vector conversion
- User interface and display
- Spatial query
  - Curser input
  - Coordinate input
- Standards support
- Help
  - On-Line
  - Context-sensitive
- Cartographic output
- Input device support
- Output device support
- User-generated macros
- Remote sensing image processing

Table 11-5: Analysis functions in the GIS World *scheme.*

annually with an increase in the number of vendors to more than 300. The analytical functions remain similar. Data from the previous year's survey were analyzed and results published by GIS

World (1989) (Table 11-6), including a grouping of functions into classes, for an analysis of the percentage of systems containing each class of functions.

Function class	Number of functions	Percentage of systems
Distance measurement	3	74-94
Buffering	5	78-90
Map algebra	5	36-78
Boolean operations	2	80-82
COGO computations	1	40
Network tracing	1	44
Remote sensing image analysis	1	26
Terrain analysis	8	26-60
Polygon operations	6	18-82

Table 11-6: Percentage of systems by function class.

STATE OF WISCONSIN MODEL

The fifth scheme is that used by the Wisconsin Department of Administration (Ventura 1991) to develop a list of appropriate GIS/LIS software functionalities for use by local governments. This scheme, the product of a format to aid local governments in their requests for proposals (RFPs) from vendors, can demonstrate how various analytical functions assist land information managers in conducting administrative, planning, management, and policy functions and responsibilities. The analytical capabilities (Table 11-7) are abstracted in a functionality matrix (Figure 11-6) that is used later in this chapter (Section IV. APPLICATIONS) to examine the use of functions for specific applications.

ERROR ISSUES

The use of GIS/LIS technology and spatial analytical operators (functions) naturally introduces errors, a phenomenon familiar to anyone who has worked with land data -- manual or automated. In certain functions such as overlay, however, errors

- User interface
- Data base management
- Data base creation and management
  - Data automation
    - Data input
    - Topological structuring
  - Attribute data association
  - Data editing and error correction
  - Terrain and other 3-D surface representation
  - Import/Export
- Display and analysis
  - Data retrieval
    - Feature
      - Selection and display by theme or layer
      - Selection and display within window
      - Selection and display by feature name or groups of names
      - Measure location
      - Measure distance
      - Measure along-line distance
      - Measure line direction
      - Measure area shape
    - Attribute
      - Selection and display by Boolean retrievals on attributes
      - Listing of attribute items associated with selected feature classes
      - Listing of attribute values of selected features
      - Frequency distribution
      - Count
      - Statistical summaries
  - Data restructuring
    - Raster to vector conversion
    - Vector to raster conversion
    - Encoding and decompression of raster data
    - Map tile or sheet appending
    - Automatic edgematching with continuity checks
    - Interactive edgematching
    - Line thinning (point reduction)
    - Line smoothing (splining)
    - Feature generalization (area to point or area to line transformation)
  - Data transformation
    - Planar transformations
      - Conformal and affine
      - Least squares adjusted affine
      - Projective
    - "Rubber-sheeting" planar transformation
      - Polynomial
      - Inverse distance weighted affine
      - Tin-based
      - Control-point coordinate look-up
      - Projection conversion
      - Datum conversion
    - Overlay
      - Graphic superimposition
      - Topological overlay
      - Automatic intersection and attribute merger
      - Manual feature creation
      - Cross-tabulation of area or number of mutual occurrences
      - Area weighted average of attribute values
      - Boolean overlay
        - Union (OR)
        - Intersection (AND)
        - Exclusive Union (XOR)
      - Topological overlay
        - Polygon on polygon
        - Line in polygon
        - Point in polygon
        - Line on line
        - Point on line
      - Sliver removal
    - Networks
      - Line and node attributes
      - Optimum path
      - Optimum distribution or collection route
      - Optimum allocation zones
    - Other geoprocessing
      - Buffering
      - Proximity search
      - Aggregate with line dissolve
      - Address matching
      - Nearest neighbor
      - Adjacency
      - Theissen polygons from points
- Data display and information product creation

Table 11-7: Software functionality checklist.

Function:		Application	Admin.	Planning	Mgmt.	Policy
Data Retrieval	Feature	by theme or layer				
Data Retrieval	Feature	within window				
Data Retrieval	Feature	by feature name				
Data Retrieval	Feature	location				
Data Retrieval	Feature	distance				
Data Retrieval	Feature	direction				
Data Retrieval	Feature	shape				
Data Retrieval	Attribute	Boolean retrievals				
Data Retrieval	Attribute	attribute items				
Data Retrieval	Attribute	attribute values				
Data Retrieval	Attribute	frequency dist.				
Data Retrieval	Attribute	count				
Data Retrieval	Attribute	statistical summary				
Data Restructuring		raster/vector conv.				
Data Restructuring		vector/ raster conv.				
Data Restructuring		map tile appending				
Data Restructuring		automatic edgematch				
Data Restructuring		interactive edgematch				
Data Restructuring		line thinning				
Data Restructuring		line smoothing				
Data Restructuring		feature generalization				
Data Transformation	planar	conformal and affine				
Data Transformation	planar	least squares affine				
Data Transformation	planar	projective				
Data Transformation	rubber	polynomial				
Data Transformation	rubber	inverse dist. weighted				
Data Transformation	rubber	tin-based				
Data Transformation		control-point look-up				
Data Transformation		projection conversion				
Data Transformation		datum conversion				
Overlay		graphic superimposition				
Overlay		sliver removal				
Overlay		area weighted average				
Overlay		cross-tabulation				
Overlay	overlay types	polygon on polygon				
Overlay	overlay types	line in polygon				
Overlay	overlay types	point in polygon				
Overlay	overlay types	line on line				
Overlay	overlay types	point on line				
Overlay	Boolean	Union (OR)				
Overlay	Boolean	Intersection (AND)				
Overlay	Boolean	Exclusive Union (XOR)				
Overlay	topol	intersect/attribute merger				
Overlay	topol	manual feature creation				
Networks		line and node attributes				
Networks		optimum path				
Networks		optimum distrib/collect				
Networks		optimum allocation zones				
Other		buffering				
Other		proximity search				
Other		aggregate/line dissolve				
Other		address matching				
Other		nearest neighbor				
Other		adjacency				
Other		Theissen polygons				

Figure 11-6: Functionality matrix.

are not only easily introduced, but also easily compounded, and very difficult to detect and correct. A discussion of errors, their sources, their impacts, and the methods of avoiding them is essential, therefore, to a discussion of spatial analytical functions.

The lack of data quality measures is a major obstacle to the effective utilization of GIS/LIS technology. Conventional wisdom suggests that the only long-term solution to the elimination and reduction of "errors" introduced by land information automation and spatial analysis is to collect all land data at the same level of validity (degree of accuracy) and reliability (precision), at the time it is needed to assure timeliness, and for the specific purpose intended to assure fitness for use. The economics of information currently preclude such an approach.

Administration, management, planning, and policy analysis of the land and its occupants "involves a balance between diverse factors of the natural environment and competing human interests ... "; as a result, these four land information functions of government "must integrate information from diverse sources" (Chrisman 1987). This integration of diverse sources of information "describes a process that goes on in our minds virtually all our waking lives as we sense, evaluate and store information about our environment" (Unwin 1981).

The overall validity and reliability of our decisions are based on this integrative process. For this process to be successful requires that we know what we are attempting to resolve, that we have the ability to translate data into information useful for the decisions before us, and that we have rules about the data to assure reproducible and valid outcomes. As we repeat this process again and again, we reduce the length and intensity of the overall process. Data become information and information is transformed into knowledge. GIS/LIS technology is simply a means to do more efficiently, effectively, and equitably what we do on an everyday basis.

Errors resulting from GIS/LIS use, then, can be classified into several sources: Errors in the data, error from natural variation and in original measurement, error caused by processing, errors from levels of measurement, and error from rules of combination (Table 11-8).

Error in Data

Until the recent need for automated data arising from the use of GIS/LIS analytical tools, issues of data quality have not tended to be a major concern of the non-mapping community. Issues of repeatable measures to known levels of measurement or to reality ("ground truth") have now become major automation issues. The

Error in data
Timeliness
Completeness
Map Scale
Reliability
Validity
Format
Cost
Error from natural variation and original measurements
Error from processing
Error from levels of measurements
Error from rules of combination

Table 11-8: Sources of errors.

ability to collect large volumes of digital data from aerial photography and orthophotography, satellites, and the global positioning system (GPS), in concert with expanded analytical functionality, requires users to consider the inherent quality of data.

Potential error sources are best understood by those who are responsible for collecting and building data bases -- manual or automated. Errors include age or timeliness of the data, completeness of the areal coverage, applicability of the map scale, reliability of the data from an areal and ground truth perspective, relevance of the data to the problem being addressed, numerical and spatial format of the data, accessibility of the data, and cost to access, collect, or convert data into a useful automated format (Burrough 1986; Larsen et al. 1978). Just as in manual methods, inappropriate use of data can result in arbitrary and capricious conclusions. Ultimately, the user or analyst must enlist professional integrity, experience, and judgment to determine the state and usefulness of the data for a particular task, application, or problem.

Timeliness of Data

Timeliness of natural resource data tends to decay at a slower rate than that of cultural data. However, as basic land information records are modernized through transactionally-based or on-line capture techniques in data collection systems, timeliness of the data as an error source will diminish. For example, as the register of deeds, the zoning administrator, and the building permit andinspection departments automate and integrate their daily activities with the property description department, a timely view of who owns the land, how is it zoned, and who plans to build will be possible. Environmental and positional data are now beginning to be captured by various on-line instruments such as weather satellites and global positioning systems (GPS) satellites. However, as one improves the timeliness of data collection, the ability to access data of exactly equal vintage becomes less realistic. Whatever the task or application, errors in the timeliness of data will remain an important factor to be considered in the use of those data.

Completeness of Data

Errors in completeness can arise if the data base does not completely cover the study area in question, or if the data are not of similar quality such as age. Studies have shown that a body of data of questionable quality that is geographically comprehensive and complete is more usable than accurate data of a scattered nature. For functioning and stable administrative political entities such as counties, municipalities, or school districts, completeness is important: each potential real estate taxpayer needs to be identified; each child must be accounted for school enrollment management. If the management or planning question requires natural boundary delineators such as watersheds or flood plain zones, all the water must be accounted for, as these units tend to cut across administrative and political units. Various levels of completeness can sometimes be solved by conducting additional surveys that fill data voids, by generalizing data to match less detailed data, or by conducting different levels of analysis to match existing data sets.

Map Scale

Map scale and the explicit collection of data depicted on a map have a direct relationship to the scale of the decision for which the map is useful and the type of analytical function chosen to manipulate the data. For example, to resolve a land administration question such as a trespass dispute over access to navigable waters by riparian owners using a criterion of "ordinary high water mark" requires, by legal precedent, on-site surveys (Zinn vs. Wisconsin 1983). In an automated world, for this land administration task, the analytical functions embedded in coordinate geometry (COGO) could be used to portray the surveyed property boundary locations. The depiction of the shoreline could be obtained from a large-scale base map (1:1,200 to 1:5,000). The analytical function of overlay could be used to spatially portray the high-water mark (shoreline) in comparison to the COGO-derived property boundary. This combination of functions could then depict the spatial extent of potential trespass, if any.

To resolve land management issues such as reduction of soil erosion from farmed land into waterways, smaller map scales (1:10,000 to 1:24,000) are appropriate given the nature of soil and the reliability and accuracy of soil erosion models such as the Universal Soil Loss Equation (USLE) (Wischmeier 1976). In this case, applicable analytical techniques might be the use of digital elevation models (DEMs)in combination with flow-routing models using automated data sources such as potential soil erosion, cropping practices, and rainfall, resulting in an estimate of soil amounts reaching the waterway. Map scale, the inherent scale of data collection, and the associated models used to manipulate the data directly limit the scale or unit of spatial analysis. Other analytical techniques might be the use of buffer analysis of a prescribed distance from the water's edge intersected with soil types, resulting in an index of potential erosion to the waterway.

Both approaches are measures of erosion depending upon the preciseness of the management question. However, the amount of analytical processing and complexity of the resultant data sets are much more complex in modeling with the USLE. Which approach is better is dependent upon the question being asked. If one wishes to regulate soil erosion, the modeling approach is most defensible. If one wishes to determine which erosive soils are spatially associated with navigable waters, the buffering approach is quite reasonable at a vastly reduced analysis cost.

Data Reliability

Reliability of the data tends be a derivative of how something was measured (precision), whereas validity of the data tends to be descriptive of how well the data reflect the question or issue being addressed (accuracy). Data might start out to be highly reliable or precise, but because of missing elements, inappropriate assumptions, or misuse of analytical techniques, the result can lead to invalid conclusions. For some automated data elements, such as surveyed property parcel boundaries, well defined collection and mapping standards are generally embedded in statutes and professional norms. Mapping reliability standards also exist for natural resources such as soils, but these natural resource reliability measures are driven more by professional and institutional convention than by legislation. This results in the need for considerably more "professional judgment" because of the spatial and transitional nature of soils as compared with a parcel boundary with a fixed and precise description. As this interest in data reliability has emerged, "truth in labeling" has been called for, whereby the source, density of observations, and ground truth employed become an explicit part of the automation product (Chrisman 1984).

For example, PLSS section corners are used over and over again to describe property as it changes ownership; these corners are relocated using the most reliable measures and valid evidence available. However, the actual location of the relocated monument may in fact not be in the correct or valid location because of an oversight of more conclusive evidence. Remonumentation law states that the valid location of a section corner monument can only be that which "retraces the original foot steps of the surveyor" who established the monument initially (Bauer 1984). This means that a monument can be reliably positioned over and over again using the best data available but, if more compelling evidence is obtained, the monument might be in an invalid location.

Data Validity

Validity is the bottom line of the overall data quality issue discussion. Validity (accuracy) is how well the measurement defines reality or a true value. Data can be up-to-date, complete, at the right scale, reliably collected, formulated in a useful way, accessible, and cost-effective, but if they are analyzed incorrectly or do not reflect the land issue being resolved, the extent of reliability will be deemed irrelevant or arbitrary and capricious.

The relevance of automated data to the administrative, management, planning, or policy issues being addressed is of major concern. The Wisconsin Department of Revenue (DOR), for example, must assess the value of land and its improvements to determine an equitable assessment for real estate tax purposes. One such measure of taxability is the inherent potential of the land to raise crops and gain economic income, irrespective of the actual farm income. To meet this constitutional requirement of equitable taxation, soil maps are used as surrogates to derive inherent production value. Soil types are classified on the basis of the ability to raise row crops such as corn, and these soils are grouped or ranked on a three-grade system (i.e., excellent, good, and poor) (Figure 11-7). Soil maps are used because the USDA Soil Conservation Service has over time developed a consistent and repeatable (reliable) set of measures of potential productivity from various soils. These measures or attributes of inherent productivity are considered valid expressions of potential land value for purpose of equitable taxation.

This eventual judgment is made by the individual or group being impacted by the decision, the decisionmaker being held responsible for the decision, or the courts being asked to mitigate the dispute. This tension between reliable but valid data remains a major dilemma for MPLIS implementors: which data will prove to be most useful for current and long-term users at a responsible cost?

Format

Burrough (1986) suggests there are three important data format issues. The first is technical. Assuming an automated environment, technical format comprises the way data are represented electronically on magnetic or disk media for storage, manipulation, analysis, and transfer between data base managers, analytical procedures, and graphical display devices.

The second issue is how the data are originally captured and structured. Data can be captured as primitives in a vector format such as points, lines, and areas or captured in raster formats. If data are in vector or polygonal form, the data structure can be graphical such as in CAD systems, topological as in many GIS platforms, or object-based as in some GIS platforms. If in raster form, the data can be represented by reflective values, presence/absence, predominant type, percents, value at centroids, or some combination of the above. The chosen data structure has a dramatic effect on how easily data can be shared and what spatial analytical functions can be employed.

The third format issue is concerned with scale of observation, conversion, storage; the type of projection utilized to transform the data; the errors of representation introduced; and the classification of the data into variables.

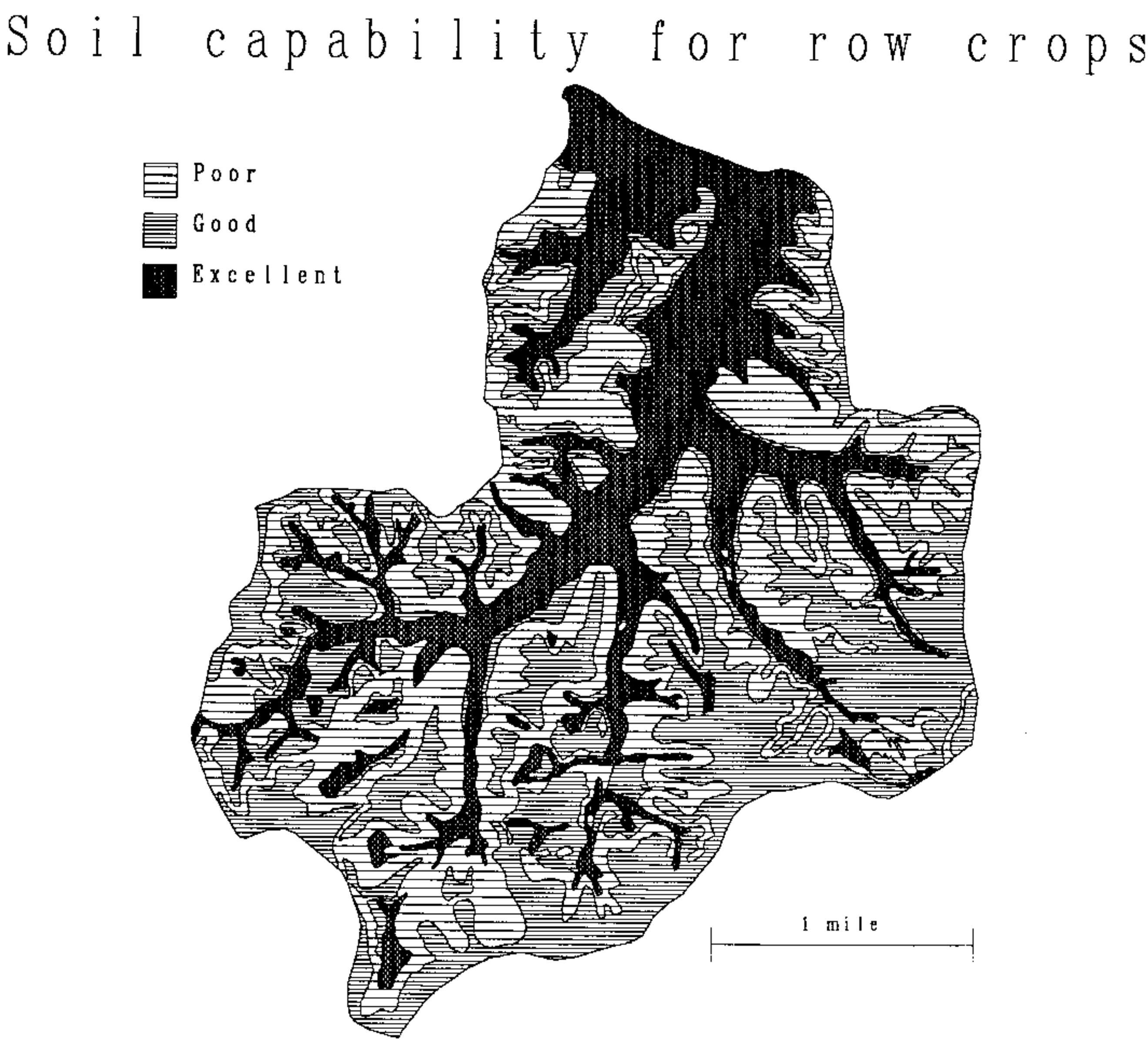


Figure 11-7: USDA SCS three-grade soils classification system.

Changing scales easily is an advantage of a modern information system. If a mathematical relationship exists between an existing scale and a proposed new scale, the change is primarily a technical procedure. Nevertheless, enlarging the scale of a data set that was originally collected at a smaller scale must be undertaken with thoughtfulness and considerable professional judgment. Transformations are of a similar nature. If there exists a mathematical relationship, the transformation is primarily technical. However, in the readjustment of the North American datum projection in 1927 to a more valid representation of the Earth's shape to the 1983 GRS datum, transformations between the two datums can be made only statistically and not mathematically. Spatial error in transferred coordinates will be generated as one moves back and forth between these two datums. The importance of these coordinate shifts depends upon the intended use of the land administration, planning, and management data.

Of particular problem is the use of existing classification schemes in a multipurpose use context. For example, how a tax assessor organizes certain data to determine the variable "swamp and waste" for real estate tax assessment purposes is probably quite different from how a botanist/ecologist organizes data to determine the variable "wetland" for regulatory protection purposes. The outcomes in terms of acres, taxes, regulations, and the property rights affected are quite different depending upon the underlying variable assumptions and associated data (Sullivan et al. 1985).

Historically, the reconciliation of classification systems was quite difficult; manual compilation and analysis limited flexibility. Automated systems offer much more flexibility by keeping the data as variable primitives and by being able to nest data sets for recompilation into other variables. Modern relational and object-oriented data structures also allow flexibility to create classification systems "on the fly" per application or issue. This ability to keep primitive views of the data is one of the real and measurable advantages of spatial information technology.

Cost

Collecting and converting data into digital form for spatial analysis remains the major impediment to the full employment and access to the benefit stream of GIS/LIS technology. Data conversion is reported to be easily 50-80% of system implementation cost (Antenucci 1990; Huxhold 1991). Over time, as systems move from manual collection and conversion methods to those that are automated and transactionally based, conversion costs will decline. Improved forms of data collection and conversion technology -- such as automated scanned digitizing, improved resolution of remote sensing and positioning systems, and new photogrammetric techniques such as orthophotography -- will also reduce data capture costs. Building and maintaining digitally structured data bases, however, will always remain as an economic restraint. Economic restraints appear in the form of relative societal importance of the problem being addressed, the associated mandates, the level of spatial and analytical uncertainty that can be tolerated, and the associated costs to collect, convert, and maintain the data in a digital form. Usually the outcome is some form of compromise between the best the technology can deliver and the ability to pay. (See Chapters 7 and 15 for more discussion about the economics of information.)

Error from Natural Variation or Original Measurements

Various state and Federal studies about land information conclude that the maps and documents that record the spatial interests and distribution about land found that "land records are not uniform nor are they related to a high quality geodetic reference system" (USDI 1990). These studies have also concluded that through the use of "a high quality" reference system, various layers or records of information can be "precisely aligned --- allowing the combination of information from multiple layers". These information layers include "parcels, roads, slopes, soils, zoning, sewer service, fire hydrants, flood plains, and land use (USDI 1990). Precision in this context refers to the ability to overlay or spatially integrate each layer and its data elements. This is similar to our definition of reliability --- the ability to repeat a measurement.

Some land features or boundaries are measured much less precisely (spatially reliably) than others, irrespective of the scale and the precision of the geodetic reference system. This is what is referred to as "natural variation" --- sometimes also referred to as that land information that tends to have "fuzzy boundaries" (Burrough 1986). More easily defined spatial objects are monumented and coordinated property boundaries and easements, pavement edges, fire hydrants, and political administrative land zoning boundaries based upon property boundaries such as the PLSS. More complex spatial objects are geographic spatial products of the natural world -- slopes, soils, and flood plains.

They constitute important records because in many parts of this nation they impact upon how land can be used and how it is regulated. Steep slopes resulting from excessive soil erosion limit use of agriculture lands; various soil types limit the location of residential development because of on-site sewage disposal requirements or flood-plain and flood-prone areas. Even the more culturally defined records of land-use zoning and land use are examples that can be characterized as having "natural variation or fuzzy boundaries." Zoning and land uses that can be attached as the sole attribute to a land ownership parcel boundary can be more precisely defined or at least defined to the same level of precision as the parcel boundary layer. Other, less well defined boundaries include shoreline zoning, which restricts building locations and on-site waste disposal location within the shoreline core. In Wisconsin, these restrictions are spatially defined and applied by such legal delineations as 1000 feet from the ordinary high-water mark of any existing lake and 300 feet from any navigable stream or river. Land use information also cuts across cultural delineations and boundaries. Large speculative single-owner land holdings adjacent to urban areas are an example. The owner might be utilizing the holdings in various ways -- some portion in a development stage, some maintained in a pre-development stage such as in agriculture use, and some in a natural or open space condition with the intent to provide public access or to include the open space for jointly owned private land such as in a condominium complex.

Some land information boundaries and attributes can be very precisely measured, and the error measured, mathematically described, and statistically reported. Other land information boundaries such as slope, soil, vegetation, and wetland "often reflect the judgment of the [resource expert] about where a dividing line, if any, should be placed" (Burrough 1986).

Natural processes and adaptation of biological phenomena such as soils and vegetation are a continuum; the boundary and attribute changes are areas of spatial transition between various soil characteristics, vegetation species, or, in the case of wetlands, the degree of "wetness." Attempting to spatially bound this natural variation is fraught with difficulty, but is legally necessary. Unless there are appropriate soils to accommodate on-site waste disposal, a building permit cannot be issued. Unless a homestead is outside the floodway, flood insurance will be required and types of land use will be restricted. Strict uniformity with respect to all land boundaries meeting the same level of precision is not technically or economically feasible or desirable. Levels of boundary and attribute "fuzziness" must be dealt with on the basis of the given mandate, the application intended, and economics of information management.

Error caused by inaccuracy of the data is a very different issue: it is a question of how well the boundary and attribute characterization of the representation reflect the object being measured. Error associated with accuracy could be as simple as mislabeling the attribute of a polygon; it could be as simple as an instrument that is poorly calibrated; it could be lack of knowledge or experience of the surveyor; it could also be the result of professional bias; or it could be the result of natural variation. Reliability (precision) is a function of how well the spatial object can be measured. Error can be introduced by mistakes, faulty instruments, lack of experience, and the natural variation that exists. Error in accuracy or validity of the data is impacted by the same factors, but statements about accuracy are dependent upon measurement interpretation and fitness for use rather than just the boundary measurement.

Error from Processing

Error from the processing of digital data is the least understood of the various potential sources of error sources. It begins with error being introduced in the capture or conversion process such as in digitizing, and can include the misuse of various spatial analytical functions such as overlay, the misuse of data given its level of original measurement, and assumptions about rules when data are used for land management and planning model conversion or are abstracted into a form that can be digested and manipulated. The error associated with this capture or conversion process impacts all subsequent use of the data -- for example, varying line widths when digitizing boundaries, particularly of spatial objects with transitional boundaries such as soils. Such errors can be managed by developing careful automation procedures and by including error and quality threshold checks.

Error introduced through the use of various spatial analytical functions is more subtle and perplexing. The use of topological overlay is a good example. The overlay function is used by a variety of disciplines for many purposes and applications. A good overlay operator remains a distinguishing feature between GIS/LIS and non-GIS/LIS products. The overlay process consists of combining two or more thematic maps and creating a third. It is conceptually straightforward, but fraught with unresolved error questions -- for example, errors created by natural variation within assumed homogeneous measures, the creation of sliver or spurious polygons along the edges of polygon intersections, and overlay with well defined boundaries such as property lines on transitional or overlapping boundaries such as soils, etc.

Nevertheless, the tool of overlay analysis remains one of the most used functions in modern GIS/LIS applications (Chrisman 1987). Professional expertise, a clear understanding of the inherent natural variation of the data being analyzed, and the spatial nature of the problem being addressed will continue, for the time being, to be the most efficient means to evaluate the reliability and validity of the analytical results.

Error from Levels of Measurement

The ease of transforming data into information, and integrating that diverse set of information into knowledge for making decisions, is related to how data were originally collected and measured. Various classification and measurement schemes have been devised. A particularly useful one for integrating and manipulating spatial data describes measurements in terms of four levels: nominal, ordinal, interval, and ratio (Table 11-9) (Unwin 1981).

Nominal measures involve no assumptions about values assigned to the data. Assignments of data are verbal or in name only ("nominal"). The data are inclusive and mutually exclusive. All spatial objects are assignable and no objects are assignable to more than one class. Examples are binary data (i.e., 0 or 1), presence/absence, and taxonomies. Nominal measures on U.S. Geological Survey (USGS) quadrangle maps at 1:24,000 include the various symbolized objects such as the presence or absence (geographically) of water, vegetation, and wetlands and labels such as city and township names.

Ordinal measures imply an ordered relationship between the objects, a consistent ranking on the application of some consistent criteria. The ranking is also verbal or in name (e.g., heavy, moderate, low). The break points between the measures are non-numerical. The break points are based on intended use, experience, and judgments. Ordinal measures on a USGS map could be the classification of roads, with the various roadway

Level	Basic operation	Example (USGS map at 1:24,000)
Nominal	Determination of equality of class; counting items	Forest, stream, water body, PLSS section lines.
Ordinal	Determination of more, less, or equality; counting items in a class	Road symbol as indication of capacity; stream order/number of branches
Interval	Determination of equality or difference of interval; addition, subtraction, multiplication, and division	Contour lines used to calculate difference in elevation and percent of slope
Ratio	Determination of equality or difference of ratio; addition, subtraction, multiplication, and division	Contour lines or spot elevations and a datum such as sea level to establish ratios between map elements

Table 11-9: Levels of measurement (from Unwin 1981).

symbols used to portray three levels of potential capability to handle vehicular traffic: two lane = heavy, paved = moderate, and non-paved = low. The order reflects potential to carry traffic using number of lanes and pavement type as the means to ordinate nominal measures.

Interval measures provide order and distance along a well defined scale. Objects can be described in meaningful units (the number of acres encompassed by Lake Michigan) and distances can be measured (the number of highway or air miles between Chicago, Illinois, and Madison, Wisconsin). Contour lines representing lines of equal elevation on USGS maps are also an example of interval measures; by subtracting one contour interval from another, the difference in elevation can be calculated.

Dividing the horizontal distance (in feet) between contour lines into the vertical difference (in feet) and multiplying the result by 100 to yield slope in percent.

Ratio measures have an inherent horizontal distance and meaningful zero point. If one assumes that mean sea level represents a vertical datum of zero, ratio measures can be made using USGS contour maps. The steps of the state capitol building in Denver, Colorado, are one mile above sea level (5,280 feet). The steps at the state capitol in Madison, Wisconsin, are 920 feet above sea level; therefore the capitol steps in Denver are 5.739 times higher than those in Madison.

Levels of measurement of spatially distributed data impact directly on the inherent long-term usefulness of the data, the method of analysis, and the certainty of the conclusions reached during the analysis. Automation allows for the manipulation of objects at all four levels of measurement depending upon the original level of measurement and the intended application. Point features such as domestic water well locations can be treated as nominal measures. By adding attribute data such as nitrate levels about the well, ordinal rankings of low, medium, and high can be created. Ratio calculations can also be conducted describing numerical differences between nitrate levels in each observed well. This can result in a ratio calculation in parts per billion, using no nitrate contamination as zero. Hydrologic units such as lakes, rivers, streams, and intermittent streams can be treated in a similar manner, given nominal measures as they exist, ordinated by ease of navigation, and ranked by interval measures by volume from attribute data.

Unwin (1981) pointed out an important limitation:

"... Although data may have been collected at one measurement level it is often possible and convenient to convert them into a lower level for mapping and analysis. Interval and ratio data can be converted into an ordinal or nominal scale... . What is generally not permitted is to collect data at one level and then attempt to map and analyze them as if they were at a higher level as, for example, by trying to add ordinal scales." To do so is a compelling desire given the flexibility of modern spatial analysis using GIS/LIS, but not to do so is an important principle."

Error from Rules of Combination

Use of GIS/LIS for determining land use and management suitabilities has become a very important use of information technology. The suitability analysis process consists of a series of analysis resulting in output that, according to Hopkins (1977), leads directly to two necessary components. The first is a procedure for identifying areas of land that are homogeneous in character and the second is a procedure for rating these areas with respect to suitability for a particular land use. This analytical process for identifying homogeneous areas and rating them also requires caution by the information technology user community, for certain rules of combination restrain the use of mathematical models.

Three major techniques by which to integrate and analyze land information to determine suitability for use have emerged over the past 30 years. They have evolved from "gestalt"-type methods in which homogeneity of resource or land-use patterns are determined by field observation, aerial photography, or topographic and thematic maps; gestalt implies that the whole cannot be derived from the parts. In the early 1970s the gestalt approach was replaced by the McHarg (1969) overlay method. This method of transparent overlays has been characterized by Hopkins (1977) as the "ordinal combination method." Nominal land resource measures are mapped as layers (e.g., soil, slope, vegetation) and overlaid using grey levels or numerical ranks (e.g., 1, 2, 3) to indicate importance or weight. The grey levels or numerical rank orders are meant to be ordinal in nature. In fact, they are often incorrectly assimilated or added and are treated as interval measures. These mistakes are fostered by the ease of data manipulation using modern information technology. Another method of analyzing information is called the "weightings and ratings game." This process consists of collecting layers of information such as soil type and assigning it a suitability weight for, say, sewerability on the basis of an agreed-upon scale of 1 to 100 and overlaying those layers with a land-use map and assigning a suitability weight for urbanization potential also based on a scale of 1 to 100. Those areas with the highest score (expressed in interval measures -- i.e., 1-100) would be the most suitable areas for new housing. Because of the measurement origins of the soil map, use of interval calculations might be responsible. However, since the land-use map was ordinal in origination, only ordinal results should be expected. The third and most acceptable type of suitability analysis consists of using explicit rules for combining layers, keeping in mind sources of data with respect to measurement levels, professional expertise, and application intent (Kiefer 1965).

Another rapidly emerging trend is to couple mathematical predictive models with the spatial analytical capability of GIS/LIS technology. These models can be of an empirical nature such as the Universal Soil Loss Equation (USLE). They can also be theoretical models based on established theory, such as viewshed and watershed representations using digital terrain algorithms. They can also be a mix of theoretical equations calibrated by field testing as in SLAMM (Wisconsin Source Loading and Management Model), which calculates potential urban pollutant loads to downstream water bodies. In the 1990s, we will see profound changes in the use of GIS/LIS technology, as these mathematical and statistical representations of spatial reality are incorporated into day-to-day land management, planning, and policy decisions. The problems of spatial error will be further exacerbated as these data-intensive models are implemented.

A Summary of Measures

What further confounds the issue of resultant error is that as part of the process of spatial analysis, we must often analyze attributes or address issues that are not readily measured outright or for which no exact measurement rules exist. Many land-use planning and management activities fall into this category: open space and residential planning, wetland protection management, and restoration and long-term ecological assessment, priority watershed management, etc. Depending upon the social and environmental values of those involved in developing and reviewing such plans, the time and money available for analysis and the societal importance of the issue, the data type collected will vary and its precision and accuracy will also vary. However, to wait until the data are perfect is not reflective of a society in need of decisions.

APPLICATIONS

Examples of the applications of land administration, planning, management, and policy analysis include town land-use administration and planning, soil erosion control planning, and water-quality policy evaluation in urbanizing regions. These applications were chosen to focus on various analytical capabilities found in GIS/LIS systems. Each application is compared with a master list of functions (Figure 11-8), and the functions used in the analysis are denoted for each application. However, a great deal of work is necessary to get the data bases into a useful form prior to analysis. Data collection, preparation, conversion, and automation are tedious, but essential.

TOWN LAND-USE ADMINISTRATION AND PLANNING

The first example, town planning, includes a brief discussion about the process of base map production and the development of other base data layers. A functionality matrix (Figure 11-8) for town planning illustrates the use of various functions associated with each of the four land-use plan components. This preparatory process eventually sets the stage for the more complex analytical phase.

Local units of government regularly develop and update land-use plans to provide a framework for future land-use policy decisions. This process often requires the assimilation of numerous local land records in both spatial and tabular format. This administration of land information is an essential first step in this type of local land-use planning effort. GIS/LIS layers automated to support this land-use plan formulation are noted in Table 11-10. MPLIS technology offers governments the opportunity to more effectively integrate, analyze, and incorporate these data into the land-use planning process. However, planners and policymakers must also understand how the technology best supports different phases of land-use plan development to realize its full potential.

Introducing GIS

LIS technology was recently put to use to support development of a land-use plan for the Township of Middleton, Dane County, Wisconsin. The Township Plan Commission (TPC) needed a plan that would help it address mounting development pressure from neighboring cities to convert rural lands to urban uses, to address potential changes in community character, and to address the impacts of development on natural resources. The TPC recognized the value of building a detailed digital data base of cultural and environmental resources to support their planning process. They felt that this information, when automated, could help facilitate plan development meetings and would allow them to communicate better with township citizens and city and county

Function:		Application	Town Land-Use Planning: Admin — Land Divisions	Planning — Land-Use Districts	Mgmt. — Property Acquisitions	Policy — Agricultural Lands
Data Retrieval	Feature	by theme or layer	●	●	●	●
Data Retrieval	Feature	within window	●		●	
Data Retrieval	Feature	by feature name		●		●
Data Retrieval	Feature	location	●	●	●	●
Data Retrieval	Feature	distance				
Data Retrieval	Feature	direction				
Data Retrieval	Feature	shape				
Data Retrieval	Attribute	Boolean retrievals	●	●	●	●
Data Retrieval	Attribute	attribute items		●		●
Data Retrieval	Attribute	attribute values	●	●	●	●
Data Retrieval	Attribute	frequency dist.				
Data Retrieval	Attribute	count	●			●
Data Retrieval	Attribute	statistical summary	●	●		●
Data Restructuring		raster/vector conv.				
Data Restructuring		vector/ raster conv.				
Data Restructuring		map tile appending				
Data Restructuring		automatic edgematch				
Data Restructuring		interactive edgematch	●			
Data Restructuring		line thinning				
Data Restructuring		line smoothing				
Data Restructuring		feature generalization				
Data Transformation	planar	conformal and affine	●			
Data Transformation	planar	least squares affine				
Data Transformation	planar	projective				
Data Transformation	rubber	polynomial				
Data Transformation	rubber	inverse dist. weighted				
Data Transformation	rubber	tin-based				
Data Transformation		control-point look-up	●			
Data Transformation		projection conversion				
Data Transformation		datum conversion				
Overlay		graphic superimposition	●	●	●	●
Overlay		sliver removal				
Overlay		area weighted average			●	●
Overlay		cross-tabulation				
Overlay	overlay types	polygon on polygon		●	●	●
Overlay	overlay types	line in polygon				
Overlay	overlay types	point in polygon				
Overlay	overlay types	line on line				
Overlay	overlay types	point on line				
Overlay	Boolean	Union (OR)				
Overlay	Boolean	Intersection (AND)		●	●	●
Overlay	Boolean	Exclusive Union (XOR)				
Overlay	topol	intersect/attribute merger				
Overlay	topol	manual feature creation	●	●		
Networks		line and node attributes				
Networks		optimum path				
Networks		optimum distrib/collect				
Networks		optimum allocation zones				
Other		buffering			●	
Other		proximity search				
Other		aggregate/line dissolve		●	●	●
Other		address matching				
Other		nearest neighbor				
Other		adjacency			●	
Other		Theissen polygons				

Figure 11-8: Functionality matrix for town land-use planning.

Policy category	Existing land uses	Zoning	Soils	Sensitive sites	Environmental corridors
Residential	X			X	X
Business/commercial	X	X		X	
Agriculture	X		X		
Recreation	X	X		X	X
Environmental/open space	X			X	X

Table 11-10: LIS/GIS layers automated to support land-use plan formulation.

officials about the rationale for their decisions. They also believed that such a data base would assist with plan implementation and allow for flexible updates to reflect future changes in community values and land use priorities.

The Township of Middleton land-use planning process involved three major components: 1) the formulation of goals and policies, 2) description and delineation of Land Use Plan districts, and 3) identification of plan implementation strategies. Information collected to support the planning process included existing land use, land ownership, population and development trends, facilities and services, ecological resources, soil productivity, and hydrology. Each land record was maintained as a separate layer in the automated LIS. This resulted in the ability to produce maps that could depict any number of cultural and natural resource features relative to tax parcel ownership. In this application, most maps were reproduced by GIS software at the scale of 1:12,000 so individual landowners could clearly identify their own property. This scale was also compatible with orthophotos available for the Township. The orthophotos were used to support land-use delineations and natural resource delineations and provide a visual base for mapped LIS data.

The first step in development of the Township's land-use plan involved the formulation of goals and policies to provide future direction for local decision makers. The goals and policies were based on information generated by a citizen survey, public input from weekly plan commission meetings, responses to newsletters mailed to all landowners to keep them informed of progress on the plan, and the information collected and presented by the Land Information and Computer Graphics Facility at the University of Wisconsin-Madison (LICGF). Those LIS data layers automated and mapped to support goal and policy development are presented in Table 11-10.

The first step in the data automation and mapping process involved the production of a planning base map. This map provided a reference to which other layers in the LIS could be registered and viewed. Construction of the base map required automating a number of important and recognizable cultural features in the Township as separate layers in the LIS -- tax parcels, major sewer interceptors, electrical utility lines, perennial streams, the urban service area, and municipal and extra-territorial jurisdictional boundaries of the cities of Middleton and Madison. PLSS corner control, derived from USGS 1:24,000 digital line graphs, was used as the spatial reference framework to register individual layers in the LIS. Given the rural character of the Township, this control scale was deemed sufficient to support the project's mapping and spatial analysis needs (Figure 11-9).

Tax parcels, needed for the base map, were automated using 1:4,800 section-based linen maps maintained by the Dane County Land Regulation and Records Department (LRRD). Automated tax parcel boundaries were converted one PLSS section at a time, and later edgematched and joined into a single seamless layer in the LIS. A unique county tax parcel identifier was then assigned to each tax parcel in the layer, using a coding scheme established by LRRD. This identifier provides for the linking of data maintained on the County tax assessment rolls, such as assessed value and ownership, to the tax parcel layer. Farm tenure information was also coded to individual tax parcels by asking TPC members to identify agricultural landowners and their current farming status and long term land use intentions. When eventually remapped in relation to environmental resource layers, tenure information was useful to Township officials in identifying potential conflicts between TPC resource protection priorities and future landowner land-use intent.

Incorporated boundaries and extra-territorial jurisdictions of the cities of Middleton and Madison were also included in the base map to provide TPC members with a visual understanding of municipal influence on town land-use authority. As the map in

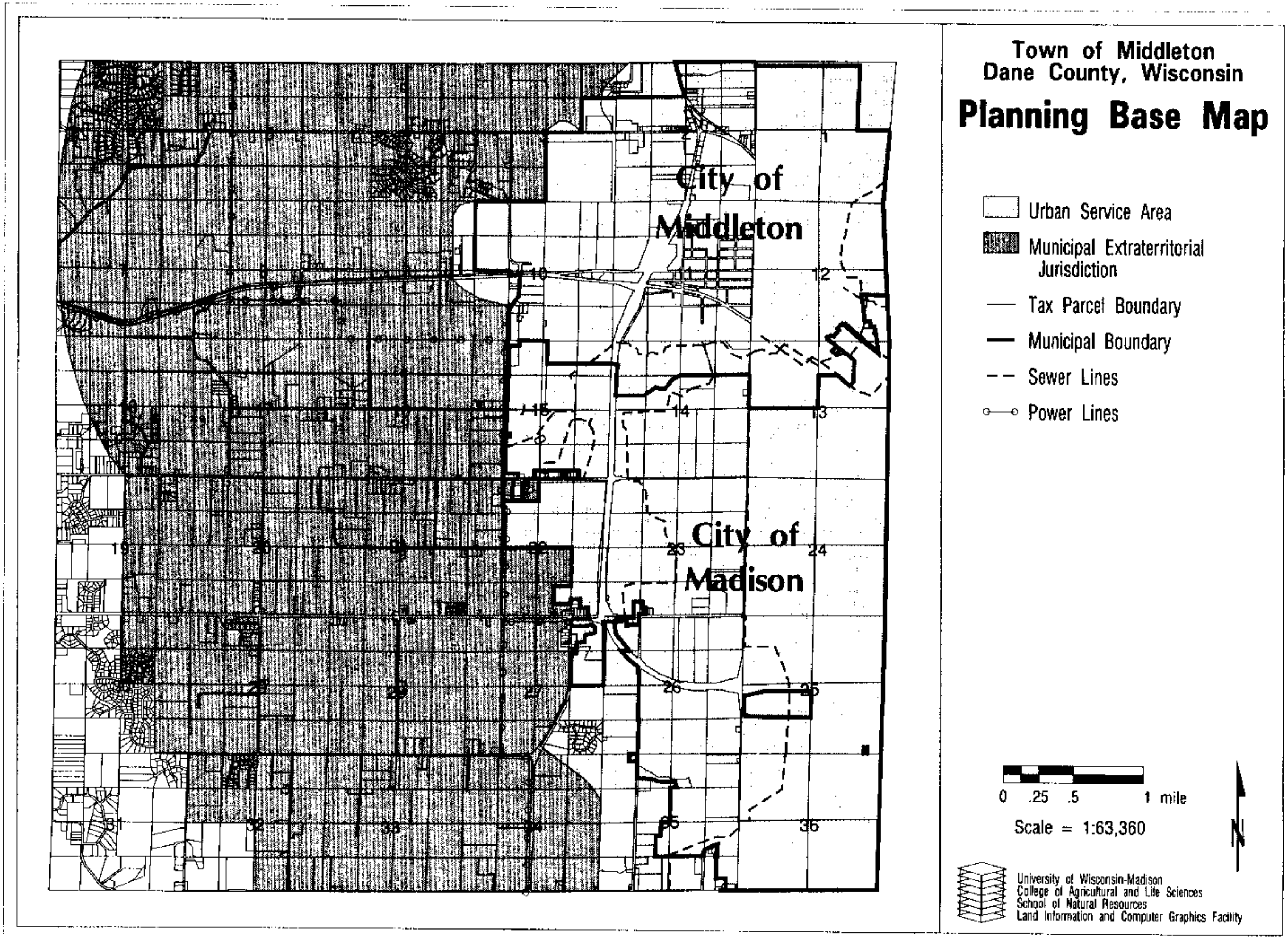


Figure 11-9: Middleton planning base map.

Figure 11-9 portrays, the two cities have collectively annexed the eastern one-third of the Township and they exert significant control over land divisions within their three-mile extra-territorial jurisdiction. The inclusion of the urban service area and major sewer and utility features in the base map enabled the TPC to identify those areas where urban development was planned and where urban services could be provided.

The second step in the plan preparation process was the creation of various layers of land information. Existing land use was the first layer constructed (Figure 11-10). To begin the process, a transparent base map was created and overlaid onto orthophotos so TPC members could identify 24 existing land uses in the town. Residential land uses were further divided into a number of separate categories on the basis of property size and type of land cover. Vacant, undeveloped residential lots were also flagged in the LIS and later remapped for guiding policies on "infill" and the creation of new property divisions in the Township. When land uses had been entered into the LIS, acreage for each land-use class were quickly available; they supplemented computer-generated maps displaying the spatial distribution of the land uses. In general, land-use information was used extensively in developing all five goal and policy categories.

The next layer that was automated was the land use zoning information (Figure 11-11). Zoning data for the two cities and for the Township were also automated and referenced to the digital base map. Because zoning information came from three different sources, it did not match along municipal boundaries and thereby required much editing. Since each unit of government maintained a unique zoning classification scheme, a standardized categorization was developed for mapping purposes. Eventually, when environmental resources and higher intensity zoning were automated and mapped, TPC members could more easily identify potential conflicts between them.

The first of two natural resource layers (Figure 11-12) identified productive farming soils in the Township. Soil mapping units for the Township of Middleton were extracted from an existing county-wide digital layer and assigned a crop productivity rating based upon the Wisconsin Department of Revenue's (DOR) three-tier soil grade classification scheme. Agricultural tax parcels were extracted from the tax parcel layer using the land-use code and overlaid with the soils layer to separate farmed from non-farmed soils.

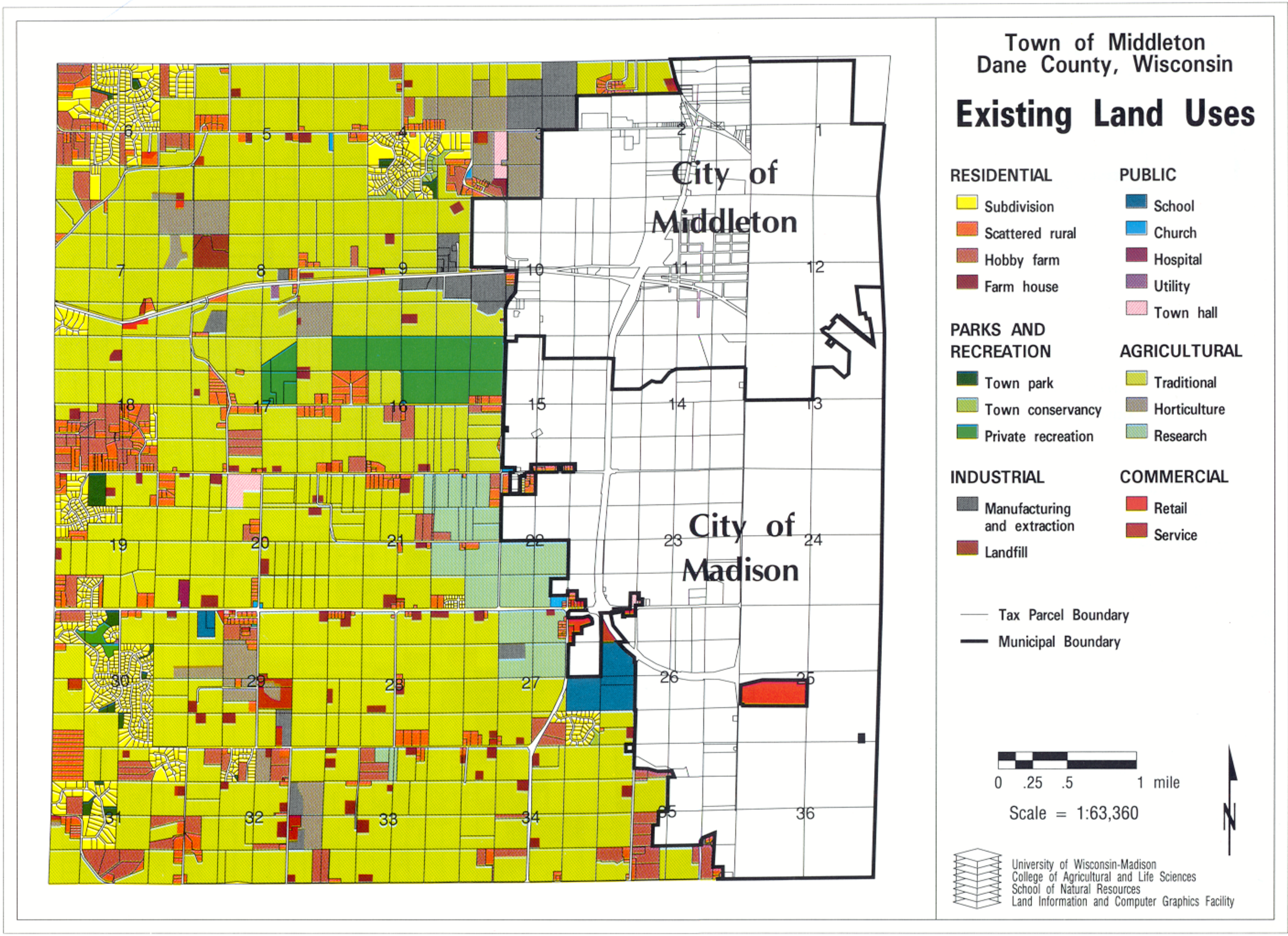


Figure 11-10: Existing land uses in Middleton.

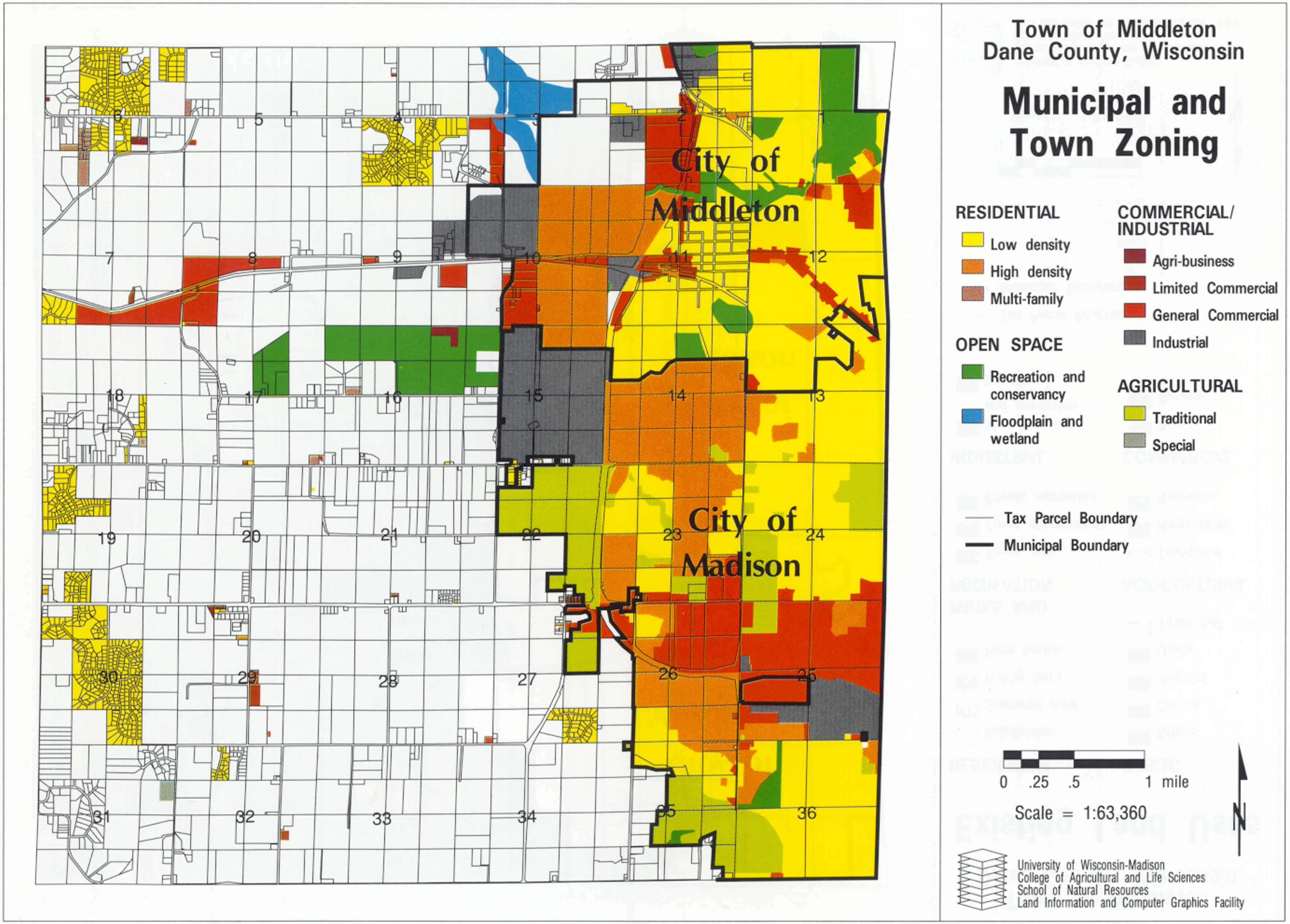


Figure 11-11: Town and municipal zoning in Middleton.

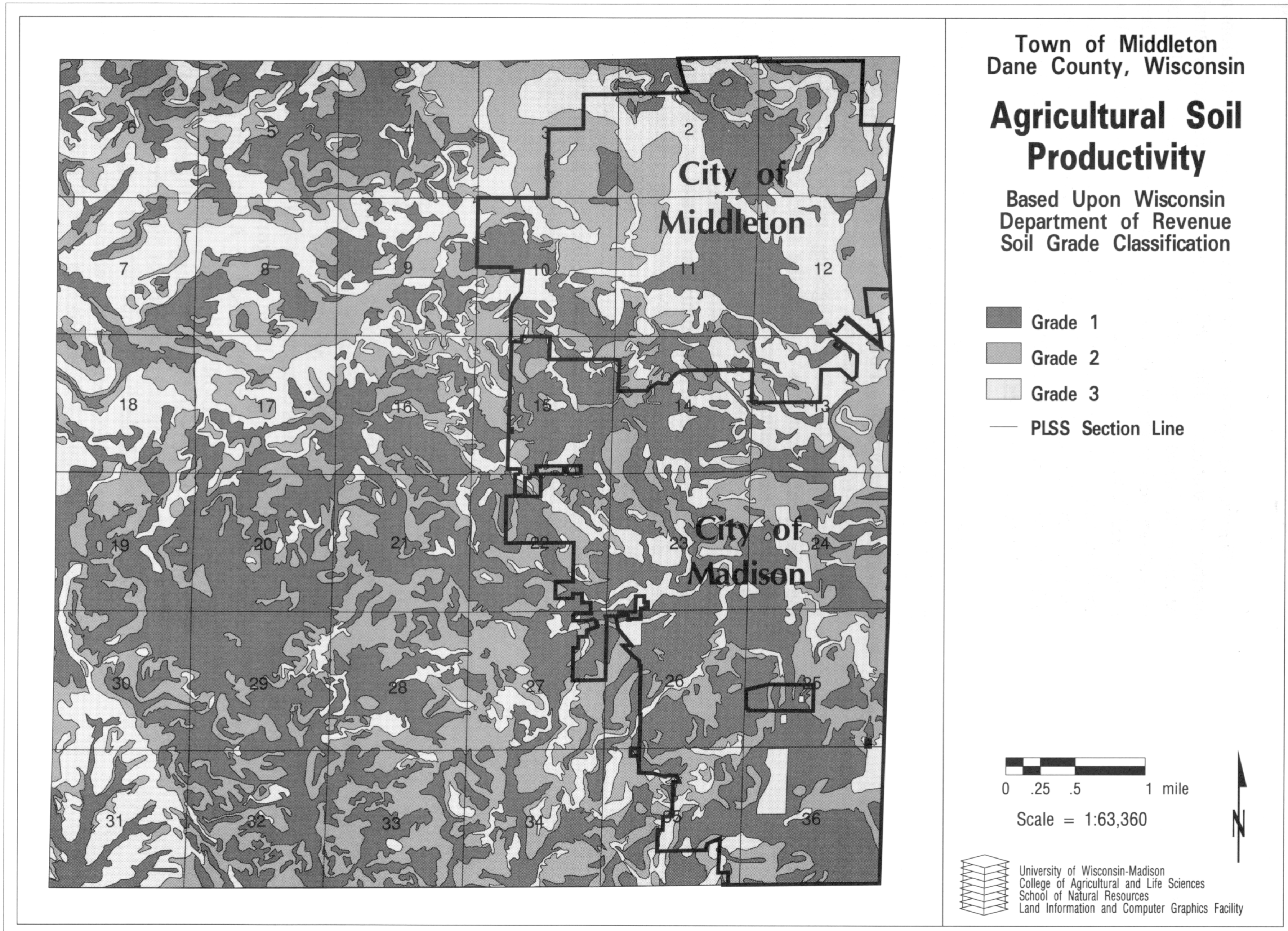


Figure 11-12: Agricultural soil productivity by DOR three-tier soil classification scheme.

The second layer of natural resources was automated from a number of sources. The TPC requested that detailed natural resource information provided by the Township's ecological consultants be incorporated into the LIS (Figure 11-13). They recognized that having this information in digital form would allow sensitive natural sites to be viewed in relationship to tax parcel, land use, zoning, and soils information already automated. This information was used to identify goals and policies specific to nine natural resource districts.

Several difficulties were encountered during the automation process. Many natural resource delineations do not have explicit boundaries because of the continuous gradient or natural variation of natural phenomena. For the sake of automation, boundaries were identified for all features, though many boundaries were coded as transition lines for highlighting and/or buffering. Despite the ecological consultants' use of the same orthophoto base for delineating their features, inexact registration of mylar overlays on the orthophotos introduced some spatial errors into the digital product. Spatial boundary registration errors were improved to a limited degree by identifying additional control on the consultants' maps during automation, and by employing special coordinate transformation functions available in GIS software. These types of problems and errors are often associated with maps prepared without automation in mind or without previous automation experience, or prepared before the establishment of conversion rules.

Agricultural Resource Goals (Policy)

Establishment of agricultural land use policy required the identification of currently productive farming soils in the Township. The coverage layers constituted by agricultural tax parcels + soil productivity were further divided by individual tax parcel. The total area of each soil grade for each highly productive parcel was computed. Parcels containing Grade 1 soils were assigned to one of three categories: >75% Grade 1; 50-75% Grade 1; and <50% Grade 1. A final map was produced showing the three DOR soil grade classes and tax parcels highlighted by percent Grade 1 category (Figure 11-14). This analysis and mapping effort would not have been possible without access to an available digital soils data base, again demonstrating the long-term multiple benefits that accrue when investments have been made in digital information in a MPLIS environment.

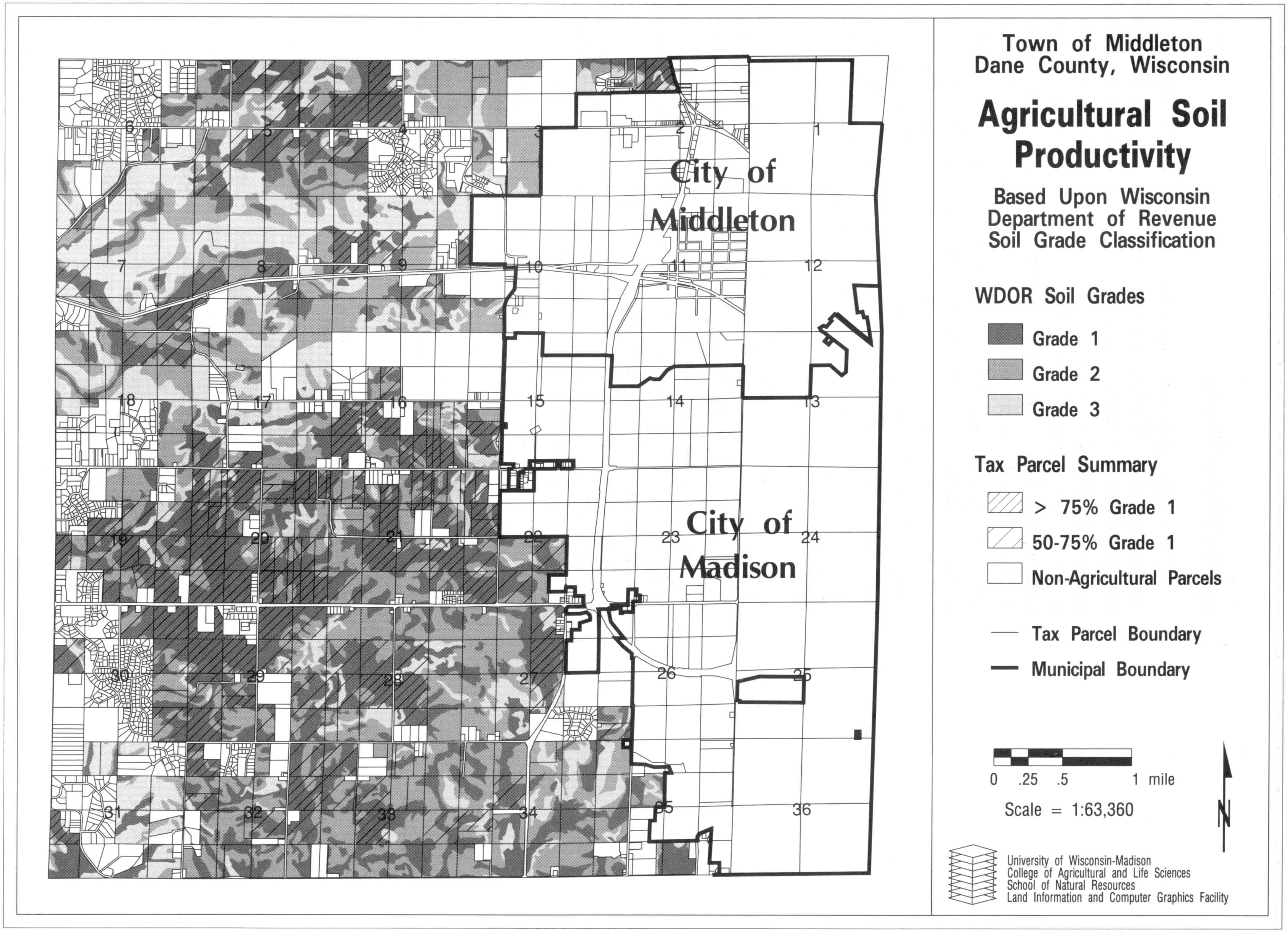


Figure 11-14: Soil productivity on agricultural lands in Middleton.

Land Use Districts (Planning)

The next step was the identification and delineation of land-use districts. The type and density of development permitted in each of the five districts was to reflect the Township's cultural and environmental patterns. Each commission member was given a set of five computer-generated maps -- a tax parcel base, existing land uses, zoning, soils, and sensitive natural sites -- along with plan goals and policies, and a personal vision of the Township, to delineate individual land-use district maps on a single overlay. These individual maps were then combined using the various overlay functions into a final, composite map of land use districts for the Township (Figure 11-15). The ability to provide scale match plots and to integrate information from various layers helped facilitate what initially appeared to be a bottleneck in the process.

The type and density of development allowed in each land-use district was a reflection, in part, of the information provided by the LIS. TPC members delineated districts, recognizing in advance that enforcement of district densities and protection of sensitive natural resources would be possible given the data layers, mapping, and overlay capabilities of their LIS. For example, the soils and agricultural land-use overlay that identifies Grade 1 soils by tax parcel could be used in reviewing development proposals that fall within the Agricultural Residential District. The conservancy land-use district was constructed by extracting selected sensitive sites from the natural resource layer and overlaying it on the other land use districts. The Conservancy/Open Space district would require 100% protection of select sensitive natural sites and institutional and recreational use parcels identified from the existing land-use layer.

Property Acquisition Program (Management)

The final step in the land use planning process was the development of a program for implementation of Township goals and policies and land use management techniques. The TPC considered many strategies to implement the Plan and discussed possible LIS products to support these strategies. Some of these strategies demonstrate the potential flexibility of a MPLIS. A property rights acquisition program was recommended to help the Township permanently protect its most valuable natural resource lands from development. Valuable lands could be ranked by integrating productive soils and sensitive natural sites and

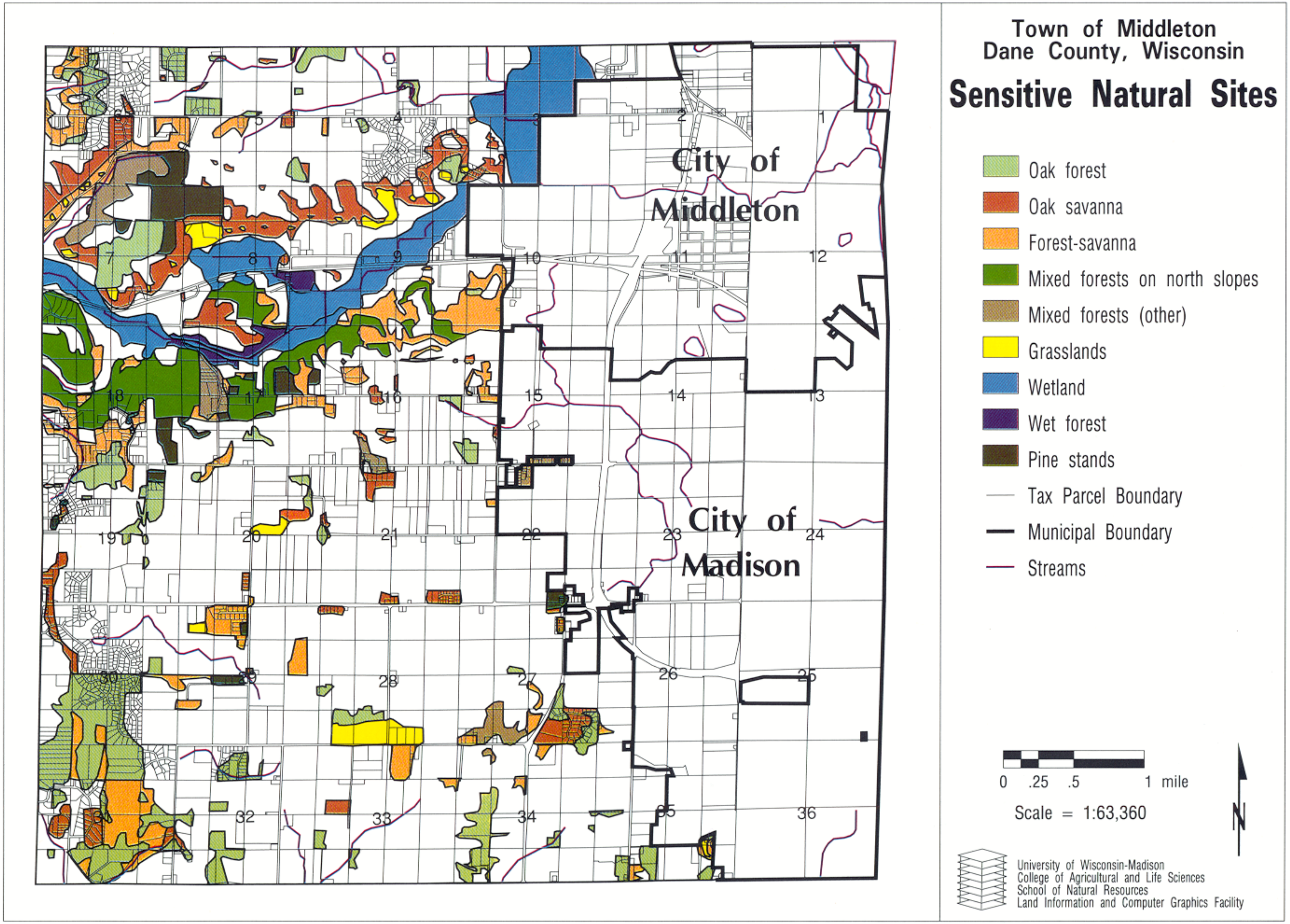


Figure 11-13: Sensitive natural areas in Middleton.

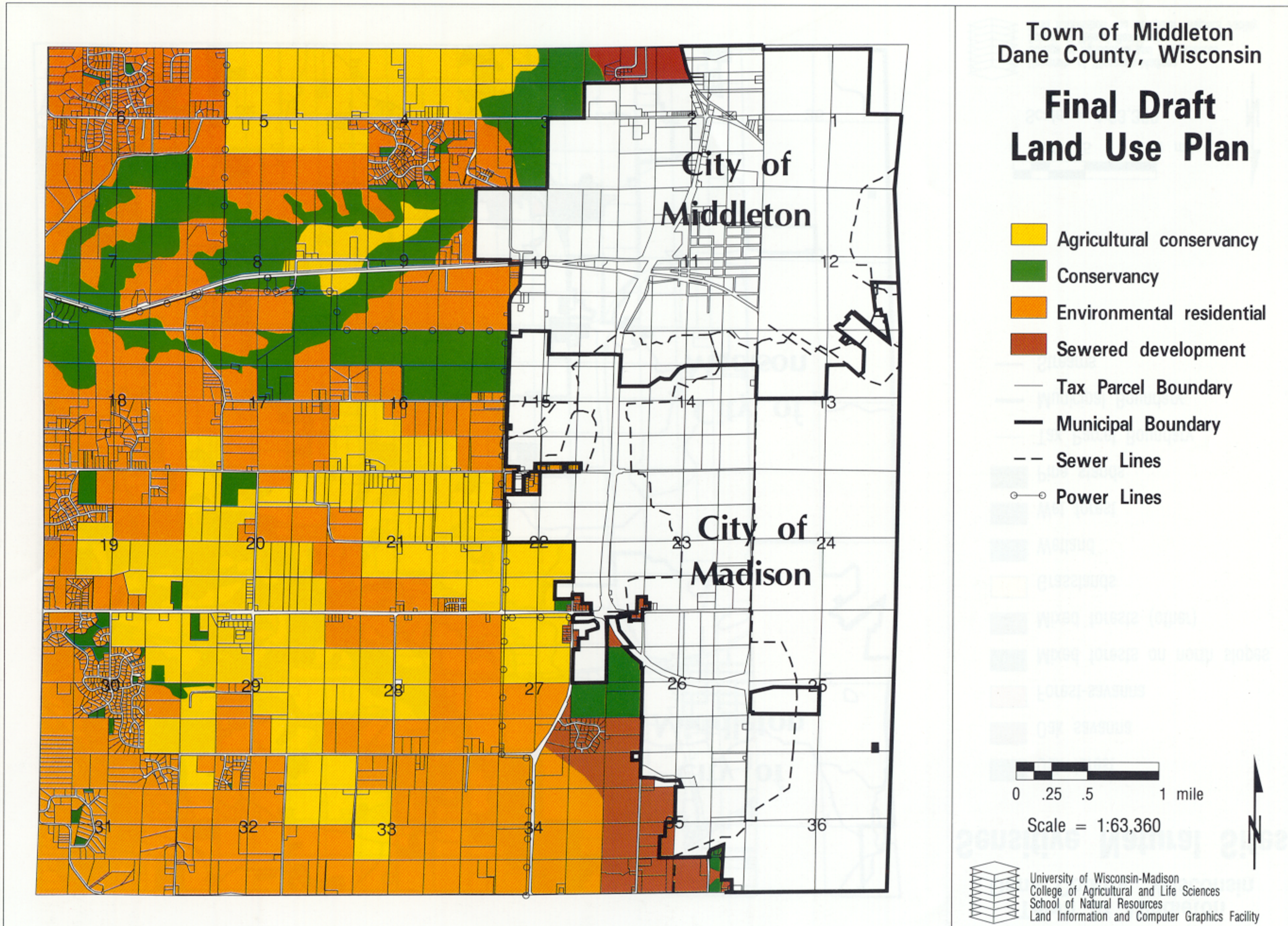


Figure 11-15: Final map for the land-use plan, created from the overlaying of five maps.

overlaying this information with the tax parcel layer. Farm tenure information, coded to individual tax parcels, could be useful in identifying potential conflicts between TPC resource protection priorities and future landowner land use intent.

Property acquisition program costs could be estimated using property tax and assessed value information derived from the County tax rolls. This information can be linked to individual tax parcels in the LIS through a unique tax parcel identifier. The purchase of land rights (i.e., development rights) or placement of conservation easements on properties in the Township could be monitored in the LIS including specific details of landowner contracts.

The technology could facilitate an educational program to promote stewardship of natural resources on sensitive lands. Site maps could be produced identifying natural resources to promote awareness of important natural resources on individual properties. Included with the maps would be recommendations for the preservation and/or management of the resources. The TPC could also use the landowner notification process as a mechanism for receiving feedback on the accuracy of natural resource delineations in the LIS.

Land Divisions (Administration)

Enforcement of land-use controls (i.e., zoning) could be aided by existence of various layers in the LIS. Spatial overlay and computer maps would help Township officials respond to development proposals or property subdivisions by quickly determining the presence of any restrictions to development as established by the land use district definitions. To promote infilling of developable land, the Plan proposed a cap on the number of vacant lots that can exist before restrictions are placed on the creation of new residential parcels. The LIS could be used to monitor the availability of vacant lots as they influence the number of new property divisions permitted.

Perceptions

Interviews with TPC members indicated that the most important perceived benefit of the technology was the ability to create and use a local data base rather than rely on more generalized information collected by state and county agencies and available at incompatible scales and resolutions. They found the software's capability to link tabular data to graphic output highly useful. The ability to map different combinations of LIS layers enhanced identification of resource patterns used as a basis for land use policy decisions. Integration of the tax parcel layer with other natural and cultural resource layers was especially important in helping the TPC treat landowners equitably when discussing land-use controls. Without the incorporation of modern GIS functionality, much of the analyses would have been too burdensome or too complex to conduct.

Soil Erosion Control Planning

Soil erosion control planning comprises both individual and composite responsibilities and so provides a focus for other analytical functionalities of the MPLIS (Figure 11-16). In soil erosion control, planning, management, and policy analyses have to respond to an existing set of mandates. The specific use and explanation of these tools to meet the requirements of Wisconsin laws and the 1985 Federal Farm Bill have been detailed for soil erosion control planning (Ventura 1988; Ventura et al. 1988a, 1988b). Congress has sustained this interest in rural land planning, management, and policy analysis by enacting the Food Security Act of 1985 and the Conservation Program Improvement Act (Title XIV) as part of the Food, Agricultural, Conservation, and Trade Act (FACTA) of 1990. More specifically, in 1990 Congress continued its interest in mitigating soil erosion by instituting cross-compliance mandates to farm managers to more effectively manage highly erodible soils.

Congress has also expanded its interest in land conservation, stewardship, and tenure by expanding the eligibility of existing and restored wetlands for inclusion in the Wetlands Reserve Program (Sec. 1237) and expanded its interest in more effective management of on-site farm chemicals in respect to surface and ground water resources.

In Dane County, Wisconsin, soil erosion control was monitored by MPLIS technology through a cooperative research project between the University of Wisconsin-Madison and the Dane County Land Conservation Department (LCD). Soil loss on agricultural parcels in the Township of Oregon was predicted by the USLE (Wischmeier and Smith 1978):

Function:		Application	Soil Conservation: Admin Lands Exceeding Standards (HEL)	Planning CRP Eligibility	Mgmt. Farm Conservation Plans	Policy County-wide Erosion Plan
Data Retrieval	Feature	by theme or layer	●	●	●	●
Data Retrieval	Feature	within window	●	●	●	●
Data Retrieval	Feature	by feature name	●	●	●	●
Data Retrieval	Feature	location	●	●	●	
Data Retrieval	Feature	distance			●	
Data Retrieval	Feature	direction			●	
Data Retrieval	Feature	shape		●	●	
Data Retrieval	Attribute	Boolean retrievals	●	●	●	●
Data Retrieval	Attribute	attribute items	●	●	●	●
Data Retrieval	Attribute	attribute values	●	●	●	●
Data Retrieval	Attribute	frequency dist.				●
Data Retrieval	Attribute	count	●		●	●
Data Retrieval	Attribute	statistical summary		●		●
Data Restructuring		raster/vector conv.			●	●
Data Restructuring		vector/ raster conv.				
Data Restructuring		map tile appending	●	●	●	●
Data Restructuring		automatic edgematch			●	●
Data Restructuring		interactive edgematch	●	●		●
Data Restructuring		line thinning				●
Data Restructuring		line smoothing				●
Data Restructuring		feature generalization				●
Data Transformation	planar	conformal and affine			●	
Data Transformation	planar	least squares affine	●	●		●
Data Transformation	planar	projective				
Data Transformation	rubber	polynomial				
Data Transformation	rubber	inverse dist. weighted	●	●		●
Data Transformation	rubber	tin-based				
Data Transformation		control-point look-up	●	●	●	●
Data Transformation		projection conversion				●
Data Transformation		datum conversion				
Overlay		graphic superimposition			●	
Overlay		sliver removal	●	●	●	●
Overlay		area weighted average	●	●	●	●
Overlay		cross-tabulation		●	●	●
Overlay	overlay types	polygon on polygon	●	●	●	●
Overlay	overlay types	line in polygon				
Overlay	overlay types	point in polygon			●	
Overlay	overlay types	line on line				
Overlay	overlay types	point on line				
Overlay	Boolean	Union (OR)	●	●	●	●
Overlay	Boolean	Intersection (AND)				
Overlay	Boolean	Exclusive Union (XOR)				
Overlay	topol	intersect/attribute merger	●	●		●
Overlay	topol	manual feature creation				
Networks		line and node attributes			●	
Networks		optimum path				
Networks		optimum distrib/collect				
Networks		optimum allocation zones				
Other		buffering				
Other		proximity search				
Other		aggregate/line dissolve		●	●	●
Other		address matching				
Other		nearest neighbor				
Other		adjacency				
Other		Theissen polygons				

Figure 11-16: Functionality matrix for soil erosion control planning.

$$A = R \cdot K \cdot LS \cdot C \cdot P \text{ where}$$

A: Potential Soil Erosion (tons/acre/year)

R: Precipitation Factor

K: Soil Erodibility Factor

LS: Length and Steepness of Slope

C: Cropping Practices Factor

P: Management Practices Factor

The soil erosion potential on the property of each landowner in the Township (Chrisman et al. 1986) (Figure 11-17) was produced by a sequence of steps. The 36 tax parcel section maps maintained by the County Surveyor (1:4,800) scale, were manually digitized using a spaghetti method (Chrisman 1986a). Topological structuring was performed automatically using GIS functions. After editing and automated edgematching, each tax parcel polygon was assigned its unique identifier, as recorded on maps maintained by the LRRD. The identifier permitted access to the tax parcel assessment classification recorded in the automated tax rolls of the County Tax Lister.

As an example, the soils map (Figure 11-18) for Oregon Township was also produced using the same technology as Westport Township, by digitizing, editing, and edgematching six (1:15,840) sheets from the Dane County Soil Survey. Particular advantages were gained from using automated checks for topological consistency, which detected unlabeled polygons, missing linework, and edge misclassifications. After "zipping" together contiguous sheets, a topologically clean coverage was available for the entire township.

Several soil mapping unit attributes were essential to the soil erosion estimation process. The K factor (soil erodibility) is shown in Figure 11-19. The LS factor (combined slope length and steepness factor) is not shown. Tolerable soil loss, T, in tons/acre/year is compared to estimated annual soil erosion, A.

A land-cover map (Figure 11-20) was produced by digitizing, editing, and edgematching six sheets of land-cover maps prepared by the LCD. These sheets were prepared by photointerpretation of 35-mm color slides from the Agricultural Stabilization and Conservation Service (ASCS), and compiling the data on the same

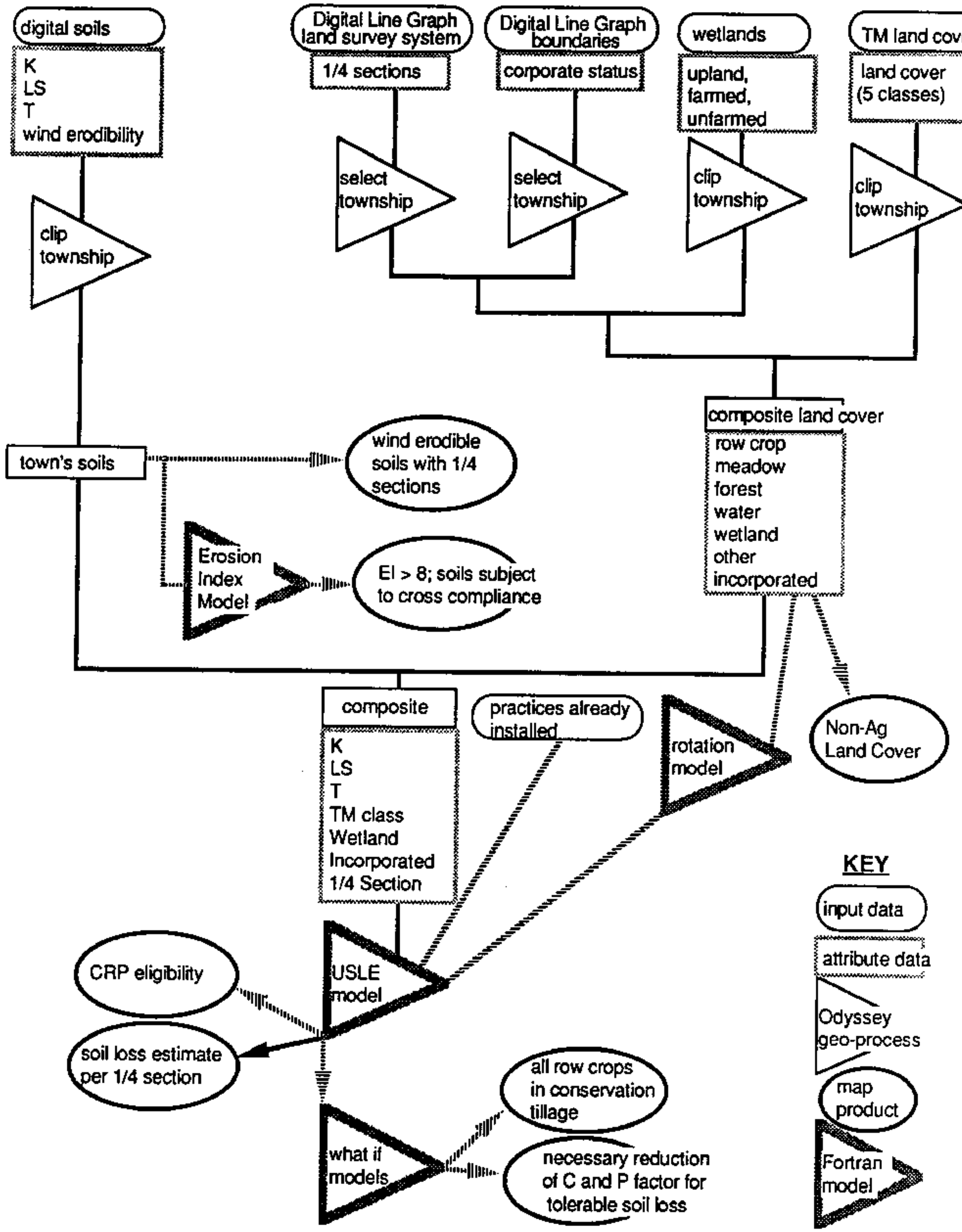
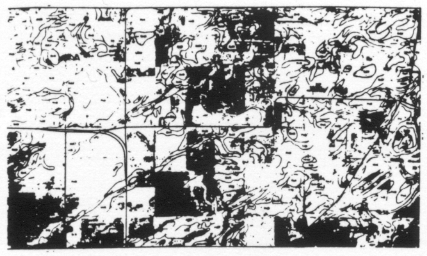
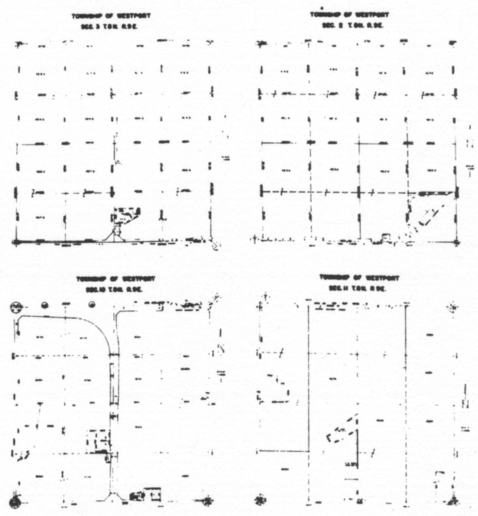


Figure 11-17: Soil erosion loss model and related processes.

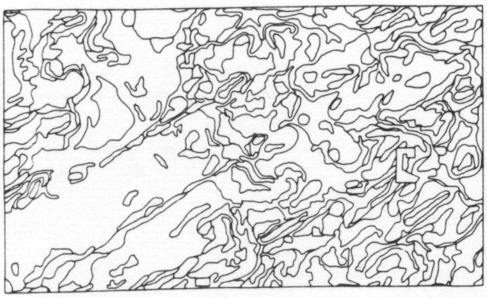
Soils Record



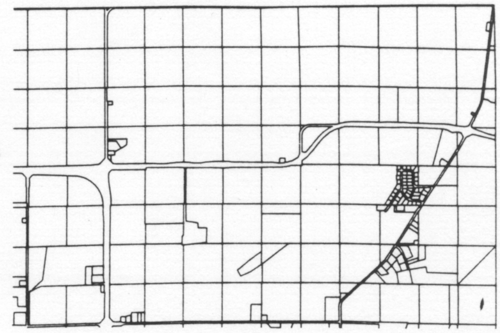
Parcel Record



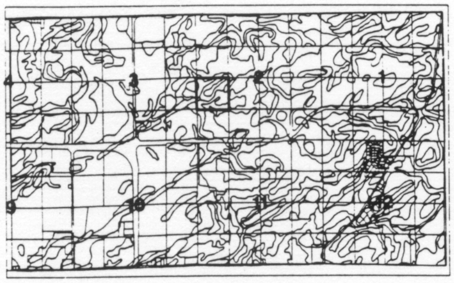
Conversion to Digital Format



Plus



Equals



Soils and Tax Parcels

SCS Soil Survey Sheet 42
Area: 3.5 x 2 miles, northeast corner of Westport Township
Dane County Land Records Project

Breakdown of soil units in a specific parcel NW ¼ of SW ¼ of Section 2, T8N R9E

State Plane Coordinates of Parcel Boundary

60894.	36375.
59567.	36381.
59567.	36389.
59555.	37713.
60887.	37694.

			Soil Erodibility	Expected Crop Yields		
Soil Unit	**Acres**	**Polygons**	K-factor	Corn bu/ac	Silage tons/ac	Hay tons/ac
RnC2	22.0	4	0.28	105.0	14.0	5.0
PnB	6.1	2	0.32	130.0	18.0	5.5
SoE	0.5	1	0.32	0.0	0.0	0.0
ScB	0.7	1	0.37	125.0	19.0	5.0
GwD2	10.1	1	0.32	80.0	9.0	3.0
RnB	1.1	1	0.28	120.0	16.0	5.5
Totals	40.5	10				
Weighted Average Yields				102.0	13.3	4.5
Total Yield for Parcel				4133.0	540.0	183.0

Figure 11-18: Use of soils and parcel layers to create digital soil erodibility data.

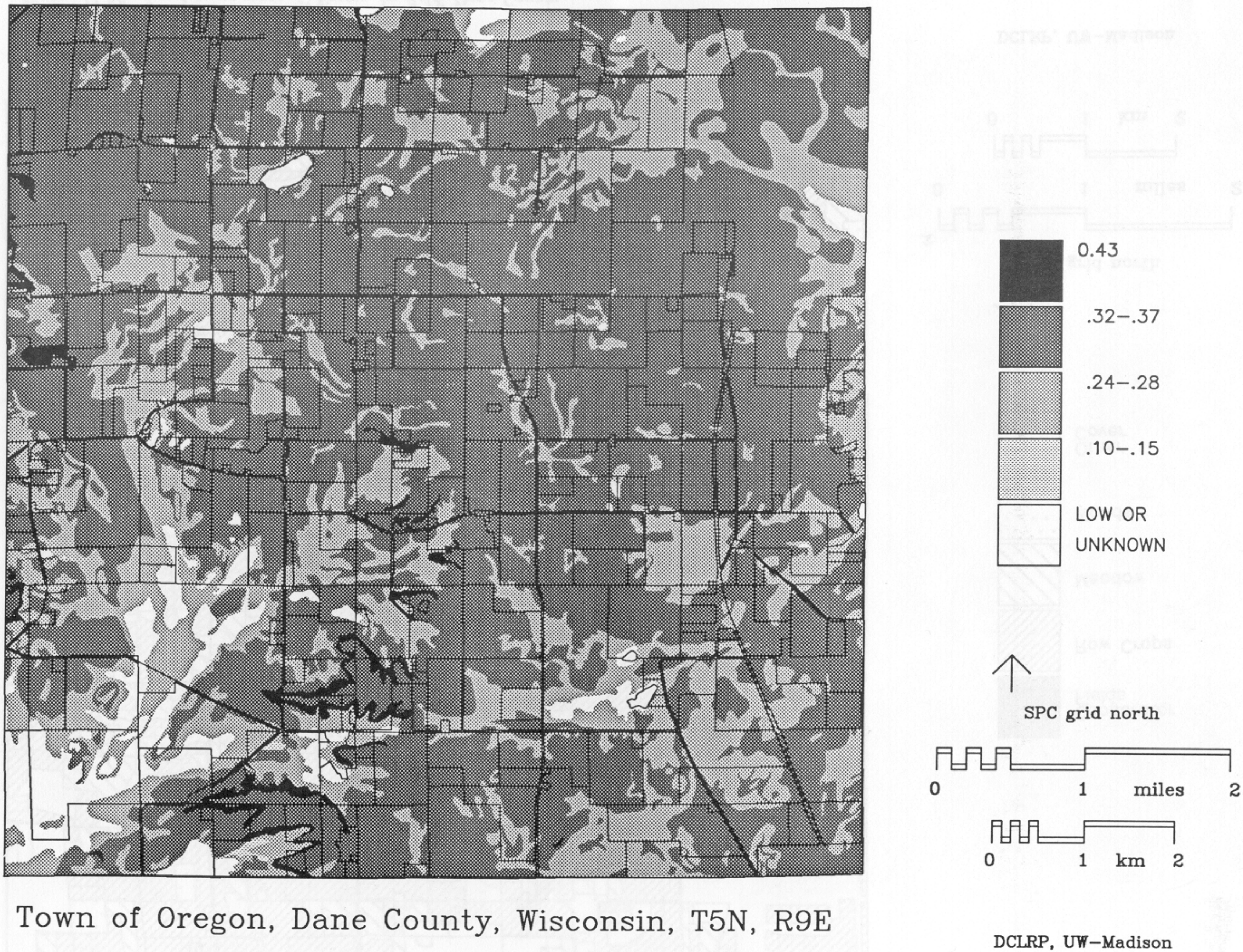


Figure 11-19: Soil erodibility factor (K) in the Universal Soil Loss Equation

53

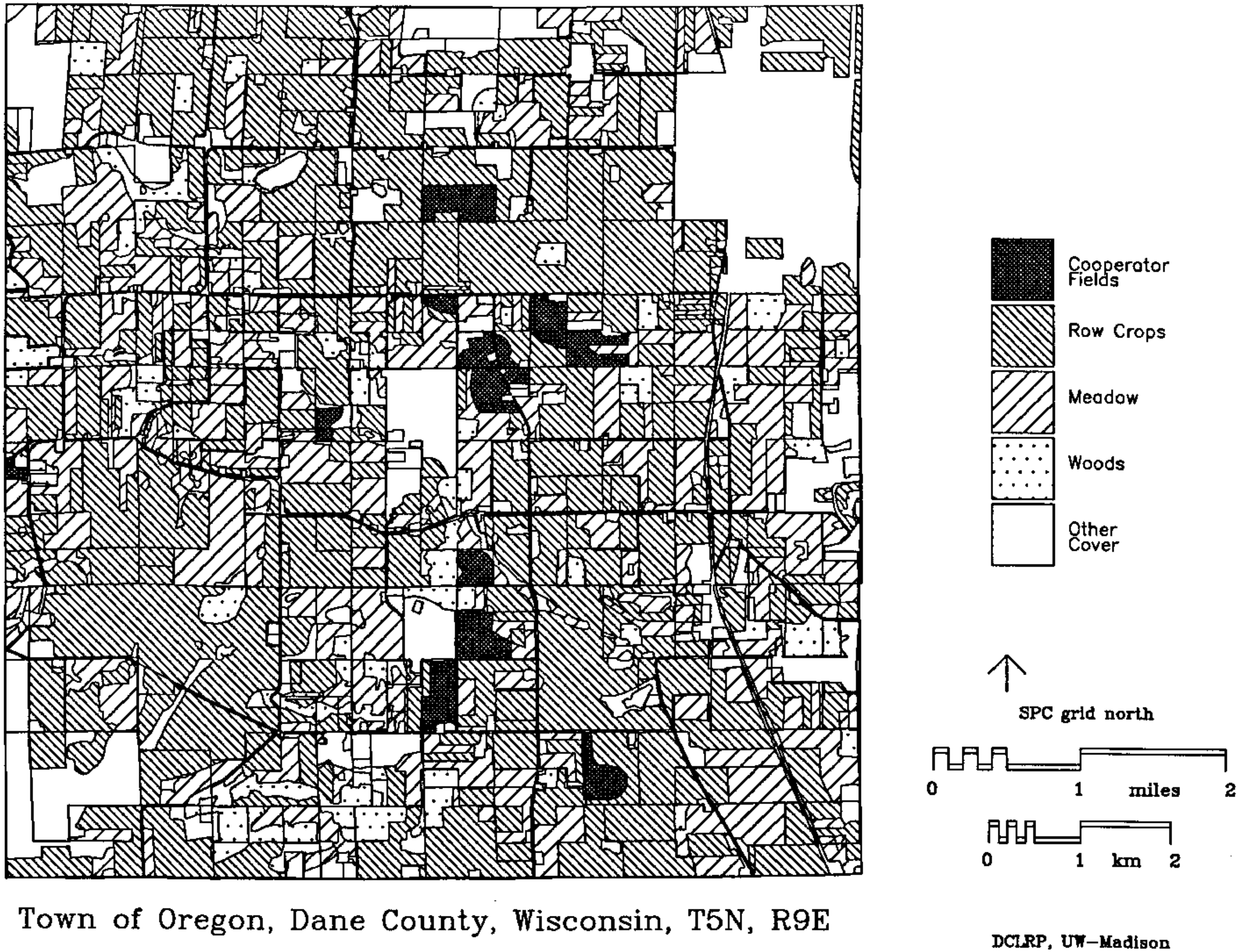


Figure 11-20: Land cover maps, C Factor, by field, Dane County.

photobase as the Soil Conservation Service (SCS) soil sheets. The cooperator fields are areas covered by agreements between the LCD and landowners. For each field, detailed USLE-related data were determined and used in the calculations. Row crops and meadows were assigned approximate C and P factors, because crop histories were not available. Areas of woods and other non-agricultural cover types were excluded from the analysis.

The rainfall factor, R, is a constant for this study area. The management practices factor, P, is known only in the few cooperator fields shown on the land-cover map. On a county-wide basis, the management practices factors were derived from remotely sensed imagery (C) and aerialphoto interpretation (P).

Figure 11-21 illustrates the result of overlaying erodibility (Figure 11-19), slope (not shown), and land-cover maps (Figure 11-20), excluding non-agricultural areas (Figure 11-17), and calculating A from the USLE. The A:T ratio is shown because legislation has specified thresholds for targeting specific areas of potential erosion on the basis of this ratio.

The uses of such analytical capabilities apply to all arenas of land administration. The planner will want to know which lands in Dane County require soil erosion control (Figure 11-22). An analysis shows that, of Dane County's 480,000 acres of farmland, about 236,000 acres will not meet tolerable soil loss standards ("T by 2000") as mandated by Ag 160 (Ventura 1988). The first column of Figure 11-16 shows the functions or operations employed. With the use of information technology, statistics are also easy to compute and aggregate (Table 11-11). The answer to the planner's question is that most of the steep and unglaciated western portions of Dane County's landscape (i.e., the Driftless Area) are susceptible to soil erosion. The drumlin fields to the east are also susceptible to erosion. It is not surprising to knowledgeable land planners that these two resource conditions are the most vulnerable to poor farm management activities.

To mitigate the impact of erosion on such sensitive land, Congress in 1985 instituted the concept of the Conservation Reserve Program (CRP). The program was set up to pay farmers over a 10-year period to keep such land fallowed in return for cash payments of about $60 to $80 per acre per year. MPLIS analysis determined which areas in the county were eligible for CRP payments (Figure 11-23). Because the Federal eligibility criteria changed after an initial assessment, another analysis was required.

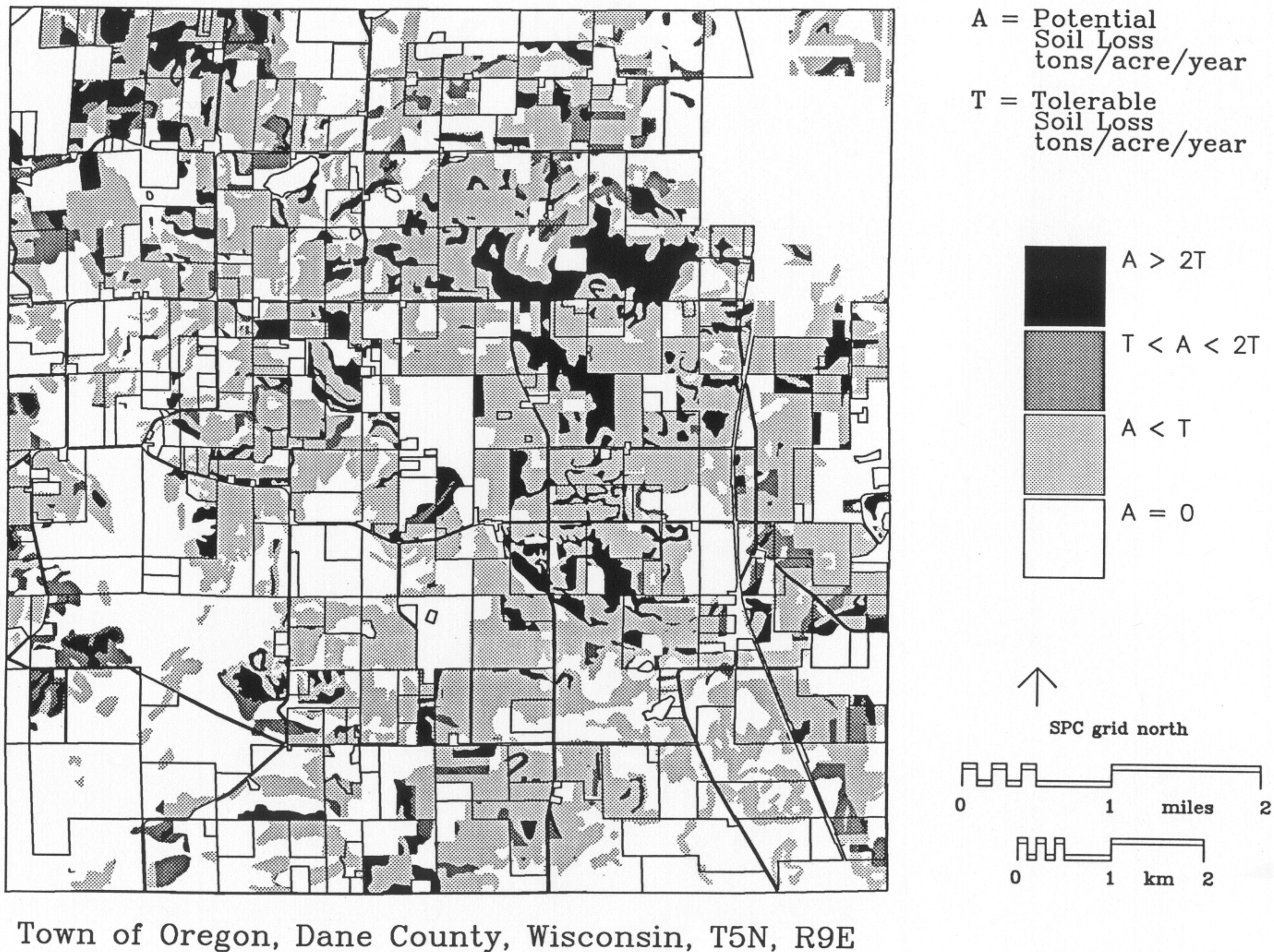


Figure 11-21: Ratio of potential soil erosion (A) to tolerable soil erosion (T)(A:T).

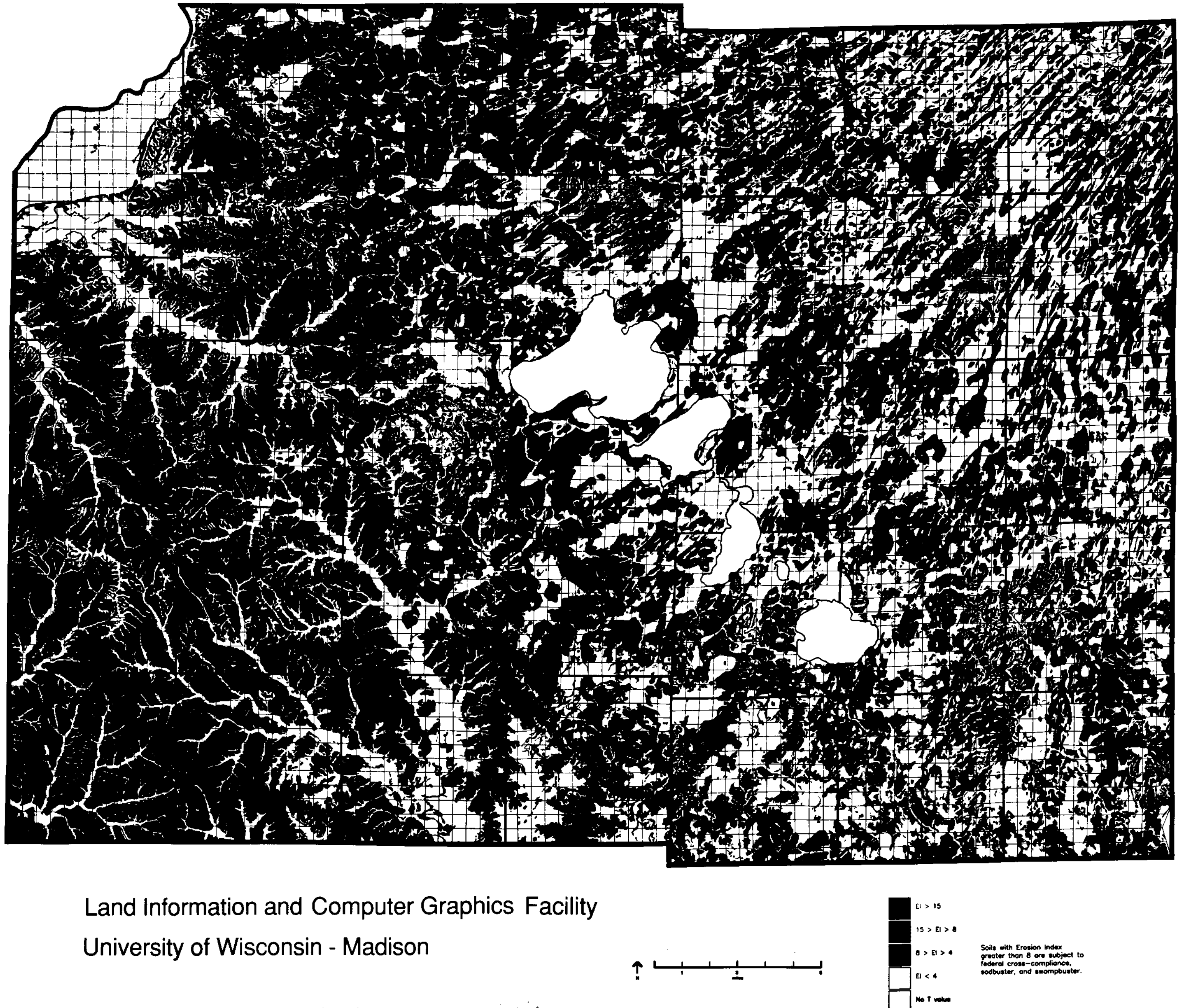
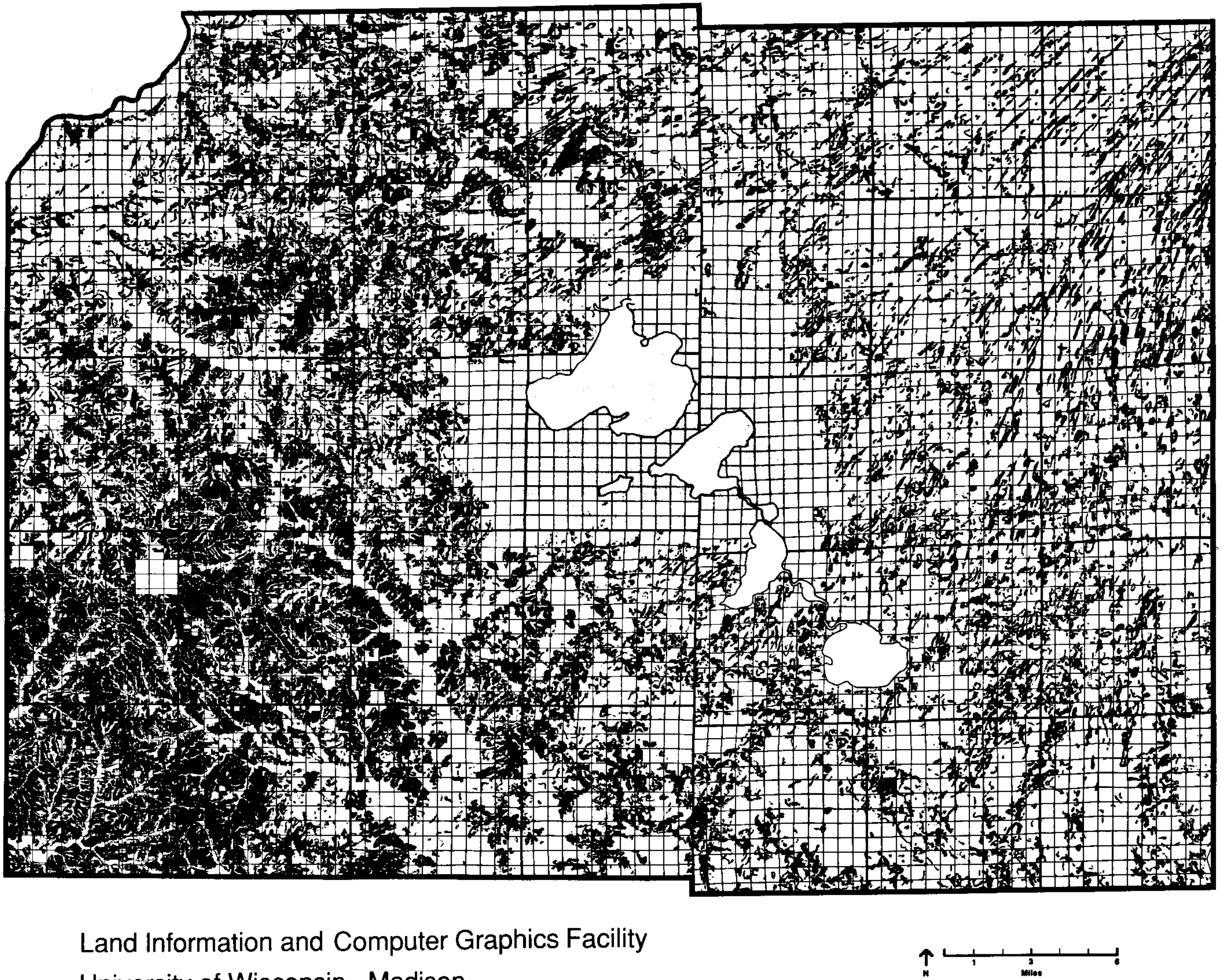


Figure 11-22: Soil erosion potential index.

CRP Eligibility

Conservation Reserve Program, 1985 Food Securities Act



Land Information and Computer Graphics Facility

University of Wisconsin - Madison

Figure 11-23: Areas eligible for enrollment in the Conservation Reserve Program.

Township	Town, Range	Ave.T Ag land	Ave. A Ag land	Ave. A Row	A/T Ag land	A/T Row	Erosion >3T	Erosion 3>T>1	Erosion <1 T
			-----(tons/acre/yr)-----				-------(acres)-------		
Mazomanie	T9R6	4.8	2.9	4.4	0.8	1.2	88	146	2357
Roxbury	T9R7	4.7	14.6	23.2	3.8	6.0	3748	2654	6765
Dane	T9R8	4.8	11.6	17.0	2.8	4.0	4182	4573	7732
Vienna	T9R9	4.9	8.3	11.0	1.9	2.6	2821	6609	9226
Windsor	T9R10	4.9	7.2	9.7	1.5	2.0	1734	6509	8251
Bristol	T9R11	5.0	5.0	8.6	1.4	1.8	1277	6824	8468
York	T9R12	5.0	8.3	10.4	1.7	2.1	1749	7854	7888
Black Earth	T8R6	4.5	9.7	15.8	3.0	5.0	1839	1142	8062
Berry	T8R7	4.6	15.2	25.6	4.0	6.7	4407	2055	7348
Springfield	T8R8	4.8	10.0	15.3	2.3	3.5	3664	4965	9633
Westport	T8R9	4.9	9.1	12.0	2.0	2.6	2037	4285	5320
Burke	T8R10	4.9	8.3	10.6	1.8	2.3	1423	4506	4375
Sun Prairie	T8R11	5.0	7.0	9.2	1.4	1.9	1199	6203	7276
Medina	T8R12	4.9	11.2	15.3	2.3	3.1	2626	4225	6925
Vermont	T7R6	3.3	21.1	32.7	8.2	12.7	5141	812	4792
Cross Plains	T7R7	3.9	13.0	20.1	4.8	7.4	5223	2053	7677
Middleton	T7R8	4.9	12.2	17.8	2.8	4.0	3054	2513	5527
Madison	T7R9	4.8	6.4	7.1	1.4	1.5	12	56	73
Blooming Gr.	T7R10	4.9	8.9	12.5	1.3	2.6	629	1634	2024
Cottage Gr.	T7R11	4.9	9.8	12.6	2.1	2.6	2380	5166	6351
Deerfield	T7R12	4.9	8.9	11.4	1.8	2.3	2080	3931	6947
Blue Mounds	T6R6	2.7	15.4	25.2	8.4	13.8	7098	2629	5529
Springdale	T6R7	3.4	15.5	23.4	6.1	9.3	8069	1301	7298
Verona	T6R8	4.2	11.7	16.6	3.3	4.7	4848	3059	7452
Fitchburg	T6R9	4.9	10.7	13.8	2.3	2.9	3353	5064	6676
Dunn	T6R10	4.8	12.2	15.0	2.6	3.1	2830	4117	4250
Pleasant Spr.	T6R11	4.7	9.0	11.6	2.0	2.6	2376	5422	6960
Christiana	T6R12	4.7	8.3	10.4	1.9	2.4	2373	6269	8553
Perry	T5R6	2.9	12.8	21.4	6.0	10.1	7471	1870	7651
Primrose	T5R7	3.3	11.6	18.3	5.2	8.2	5791	2473	8531
Montrose	T5R8	3.8	10.8	16.0	4.0	6.0	4246	2737	9115
Oregon	T5R9	4.7	9.8	13.5	2.2	3.1	2982	3647	8086
Rutland	T5R10	4.7	8.3	10.7	1.8	2.3	2365	5288	8609
Dunkirk	T5R11	4.7	8.8	0.6	1.9	2.3	2478	6177	7406
Albion	T5R12	4.8	8.1	10.3	1.7	2.2	1746	5718	7057
Area weighted average			10.5		3.0				
Total							109,337	134,486	236,190

A = potential soil loss; T = tolerable soil loss.

Table 11-11: Summaries of soil erosion estimates for Dane County.

According to the subsequent analysis, about 160,000 acres were deemed eligible for CRP, whereas initial Federal CRP eligibility estimates were only about 100,000 acres. The underestimate of about 60,000 acres was the result of an inability by Federal planners and policy analysts to utilize the detailed soil maps comprehensively and systematically across the county. Given the CRP payment levels, this underestimate of eligible acreage was not trivial. Their data came from the National Resource Inventory (NRI) sampling process, which proved insensitive to the resolution and grain of the drumlin landscape.

Because both state and Federal mandates impact site-management decisions (e.g., field by field), the macro- (or county-wide) analysis was not adequate for implementing the law. By law, soil erosion control planning takes place at the property/landowner/manager level. As described earlier in this chapter, the State of Wisconsin is an example of mandating individual land owner accountability. In 1981, it created a program to reduce soil loss (Chapter 92 of Wisconsin State Statutes).

A manager, then, might want to know which landowners require soil erosion control plans. Micro-analysis requires the manipulation of the MPLIS data base in a parcel-by-parcel manner. Such an analysis has been conducted for the Township of Oregon. Applying a modified version of the USLE for each farm landowner in Oregon Township yields an illustration of the distribution of non-compliance ($A > T$) by ownership units.

The average A:T ratio was computed for whole units of landownership by area-weighted average of cropland within a farm. Figure 11-24 illustrates which parcels and landowners will not be in compliance ($A > T$) unless they employ some additional conservation management procedures. Because the overall data base also includes the name and address of each landowner, those responsible for erosion control are explicitly identifiable. Column 2 of Figure 11-16 shows the functions employed.

When the lands and the people have been identified, the issue of actions to be taken arises. The policy analyst then will want to know which soil conservation control practice is most effective. Soil erosion control is possible by using various structural and non-structural methods. Non-structural methods tend to be the least costly to implement. One such non-structural technique is called "conservation tillage." This technique consists of leaving row-crop residue on the field as a means to reduce the impact of rain on the soil. The USLE can be re-run incorporating the policy analysis question of what would happen to compliance if conservation tillage were required of all farmers. Nearly all parcels would be brought up to the acceptable level ($A < T$) (Figure 11-25). Across Dane County, this would bring land in compliance

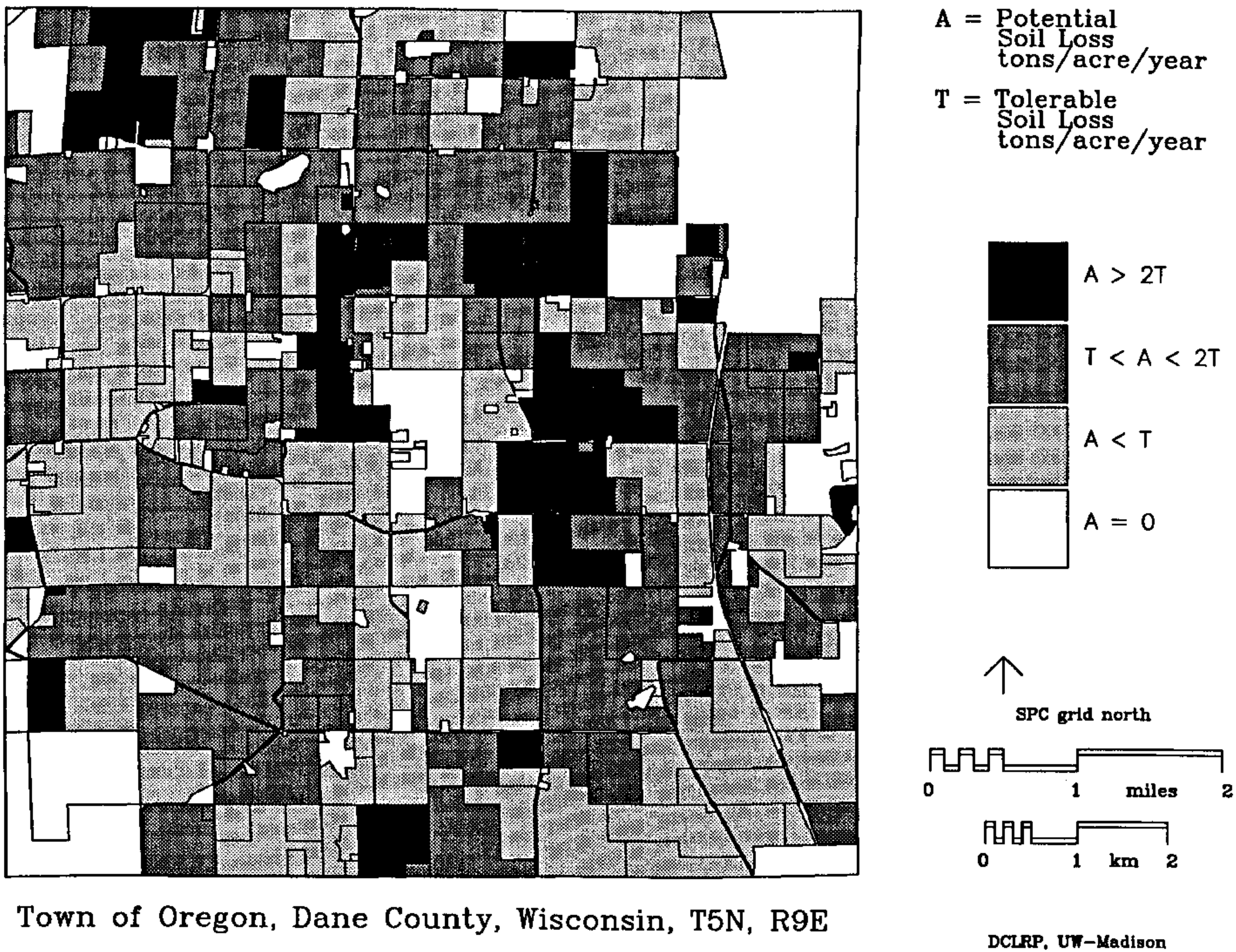


Figure 11-24: Landowners in non-compliance with soil erosion control mandates.

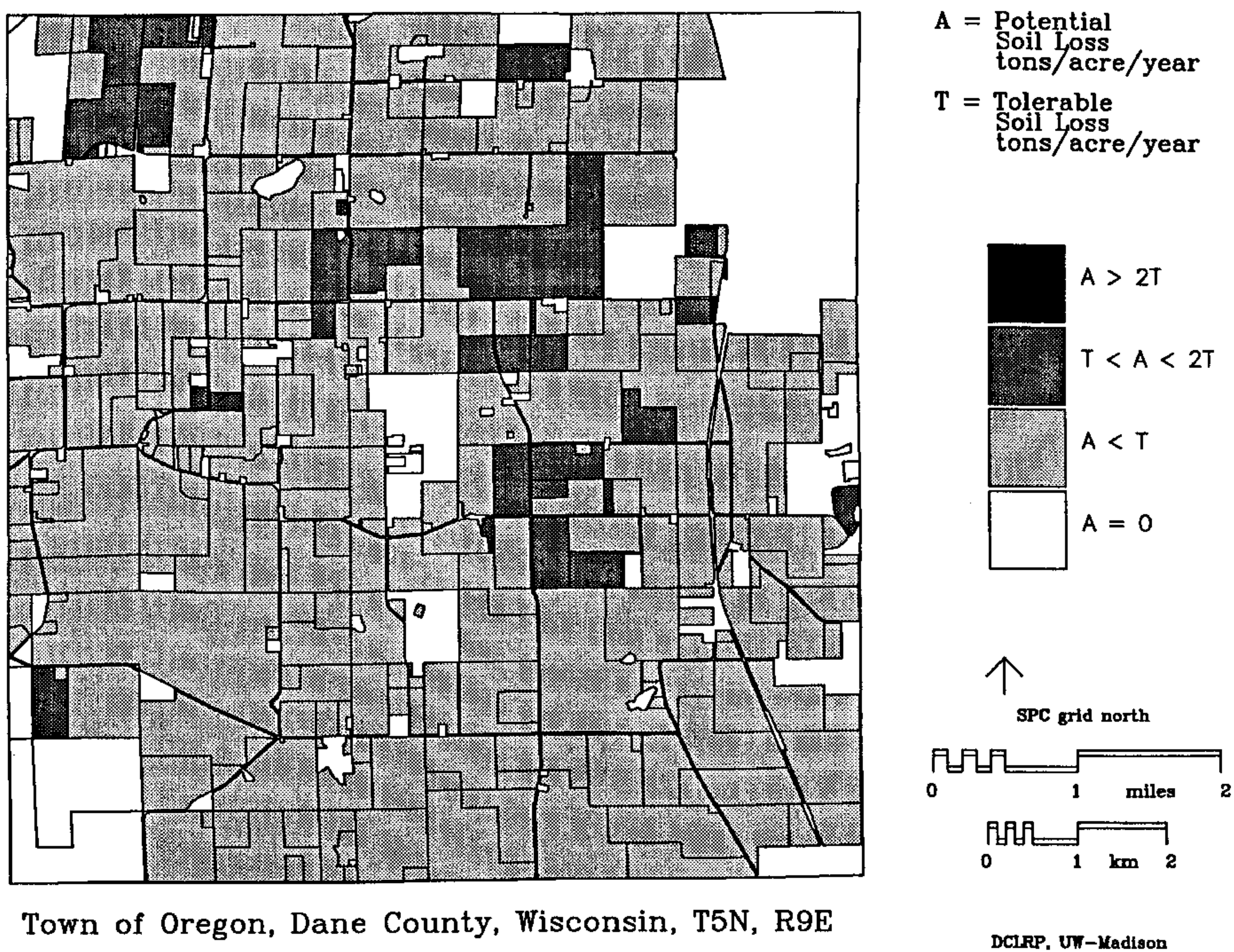


Figure 11-25: Effects of adopting conservation tillage on erosion control efforts.

to about 355,000 acres. Column 3 in Figure 11-16 enumerates the functions used for this analysis.

The ability to ask and answer these "What if" questions resulted in a major savings of time for conservation planning staff. It was also convincing to county officials who were required to endorse the final planning and management procedures for meeting compliance with the Federal and state mandates.

Other questions of policy relate to issues of land tenure. Planners and policy makers will want to know which landowners tend to be less conservation-minded (Figure 11-26). Comparing resident landowners with absentee landowners can show that lands owned by absentee landowners contribute more to soil erosion than do on-farm owners. Merging landowner names with tax mailing address ZIP codes revealed a loophole in Wisconsin's soil erosion control law: out-of-state owners do not qualify for farmland preservation income tax credit -- the incentive portion of the cross-compliance provisions.

WATER-QUALITY POLICY ANALYSIS

The use of an MPLIS in evaluating the potential soil sedimentation and pollutant impact on waterways from proposed land development plans illustrates how an MPLIS can be used to address -- a planning question: which land-use plans will result in the greatest contribution of sediment and pollutants to a waterway? -- , a management question: which sub-watersheds will require the most water-quality control measures and which landowners will be responsible for most of the soil erosion? -- , or a public policy question: what configuration of land-use types minimizes sedimentation impacts to waterways?

In the Township of Burke in Dane County, a proposed major new commercial development raised questions about its effects on water quality in the Yahara-Monona Watershed. Particular concern arose over the potential increase in sediment loadings into the waterways from fragile lands. At issue was the increased density of human activity from associated secondary development; a critical variable has been whether increased open space could ameliorate the effects on urban runoff on water quality in the area.

To assess the alternatives, six land-use scenarios were considered by local land planners and policy making officials: (1)

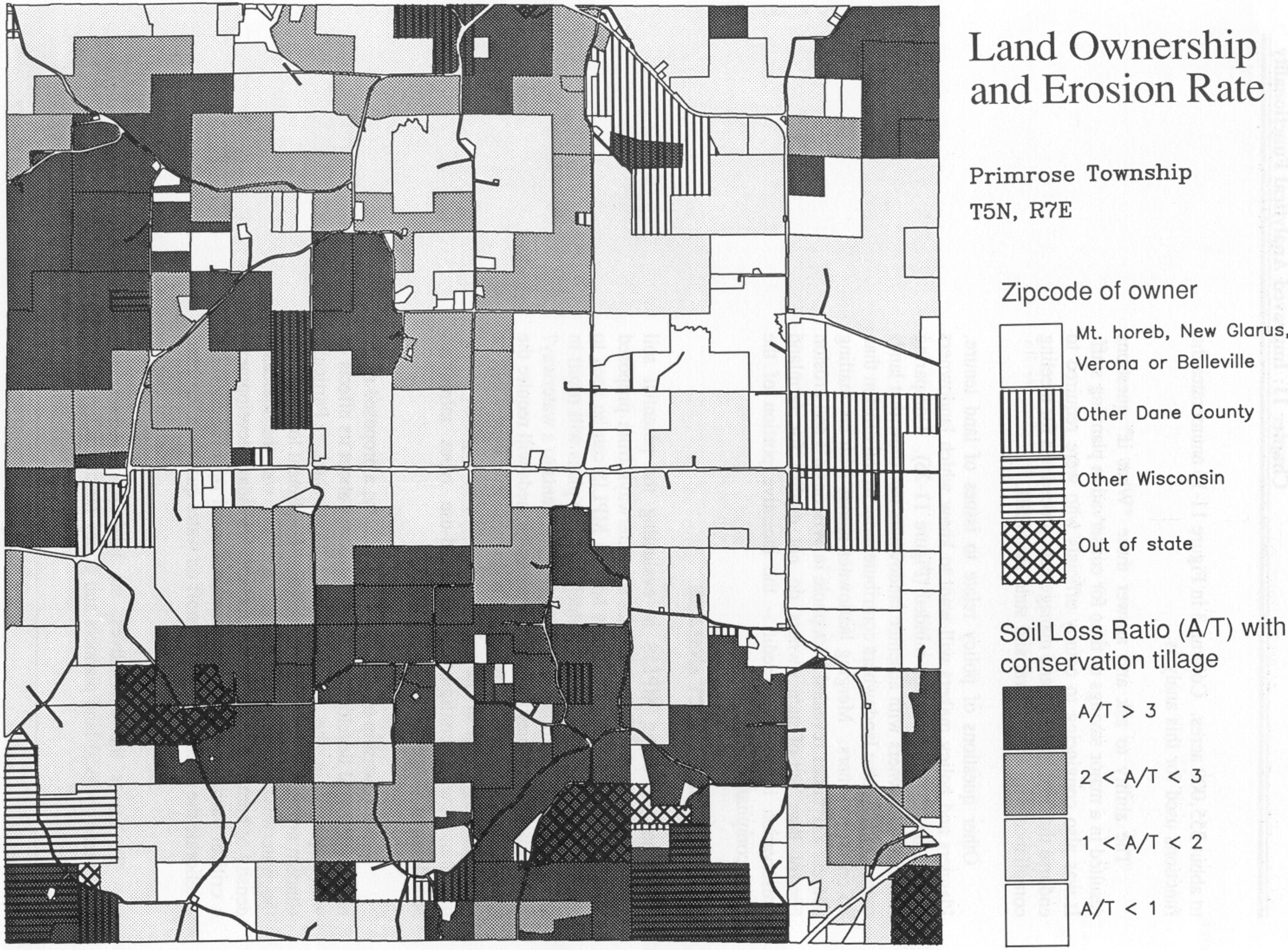


Figure 11-26: Land ownership and erosion rate.

the current land-use plan, (2) a modification of the plan, which would incorporate the protection of agricultural lands and environmental corridors, (3) plan buildout, which would incorporate zoning as an interpretation of land use where no planned land use exists, (4) zone buildout, which would assume all lands would be developed as zoned, where the planned land use would be less intensive than the zoned use, (5) modifications to the plan buildout, which would call for more open space in the final design, and (6) similar modifications to the zone buildout (Thum et al. 1990).

Analyses were made using various spatial analytical tools including overlay and buffering capabilities and digital terrain modeling functions (Figure 11-27). The sediment loading predictions were derived by connecting the LIS data base with the empirically derived water-quality model SLAMM (Pitt 1987a, 1987b). SLAMM was developed by the Wisconsin Department of Natural Resources (DNR) to predict nonpoint pollution runoff from urban development in critical watersheds around the state. Because SLAMM is basically a numerical and tabular model, interfacing it with the MPLIS provided additional analytical flexibility. More scenarios were possible and visual display made the outcomes potentially more understandable to policymakers. The reductions in nonpoint source sediment loadings between the plan buildout scenario and the modified plan buildout scenario have been mapped (Figure 11-28). The differences in sediment loadings are not trivial (Table 11-12).

Not only does the LIS illustrate which sub-watersheds will have reduced sediment loadings when more open space is incorporated into the plan, but it can ascertain which landowners will be affected by modifications to the existing land-use plan. It also clearly demonstrates which sub-watersheds are the most crucial for water-quality protection. The analysis numerically and graphically demonstrates the role that open space plays in water-quality protection.

Such analyses can give both planners and landowners the tools by which to forecast the results of their actions. That knowledge advances the opportunities for making optimum choices in safeguarding the land.

Function:		Application	Water Quality – Admin: NPDES Permits	Water Quality – Planning: Hydrologic Modelling	Water Quality – Mgmt.: Street Sweeping	Water Quality – Policy: Water Resource Inventory
Data Retrieval	Feature	by theme or layer	●	●	●	●
Data Retrieval	Feature	within window			●	
Data Retrieval	Feature	by feature name	●	●	●	●
Data Retrieval	Feature	location	●	●	●	
Data Retrieval	Feature	distance			●	
Data Retrieval		direction			●	
Data Retrieval		shape				
Data Retrieval	Attribute	Boolean retrievals	●	●	●	●
Data Retrieval	Attribute	attribute items		●		
Data Retrieval	Attribute	attribute values	●	●	●	
Data Retrieval	Attribute	frequency dist.		●		●
Data Retrieval	Attribute	count				
Data Retrieval	Attribute	statistical summary	●	●	●	●
Data Restructuring		raster/vector conv.		●		
Data Restructuring		vector/ raster conv.		●		
Data Restructuring		map tile appending				
Data Restructuring		automatic edgematch	●	●	●	●
Data Restructuring		interactive edgematch				
Data Restructuring		line thinning				
Data Restructuring		line smoothing				
Data Restructuring		feature generalization	●		●	
Data Transformation	planar	conformal and affine	●	●	●	●
Data Transformation	planar	least squares affine				
Data Transformation	planar	projective				
Data Transformation	rubber	polynomial				
Data Transformation	rubber	inverse dist. weighted		●		
Data Transformation	rubber	tin-based				
Data Transformation		control-point look-up	●	●	●	●
Data Transformation		projection conversion		●		
Data Transformation		datum conversion				
Overlay		graphic superimposition	●		●	
Overlay		sliver removal				
Overlay		area weighted average	●	●		●
Overlay		cross-tabulation		●		●
Overlay	overlay types	polygon on polygon		●		●
Overlay	overlay types	line in polygon	●	●	●	●
Overlay	overlay types	point in polygon	●	●	●	●
Overlay	overlay types	line on line				
Overlay	overlay types	point on line			●	
Overlay	Boolean	Union (OR)				
Overlay	Boolean	Intersection (AND)		●	●	●
Overlay	Boolean	Exclusive Union (XOR)				
Overlay	topol	intersect/attribute merger	●	●	●	●
Overlay	topol	manual feature creation				
Networks		line and node attributes	●	●	●	●
Networks		optimum path			●	
Networks		optimum distrib/collect	●	●	●	
Networks		optimum allocation zones				
Other		buffering		●	●	●
Other		proximity search				
Other		aggregate/line dissolve		●	●	
Other		address matching			●	
Other		nearest neighbor		●	●	
Other		adjacency		●		●
Other		Theissen polygons		●		

Figure 11-27: Functionality matrix for water-quality analysis.

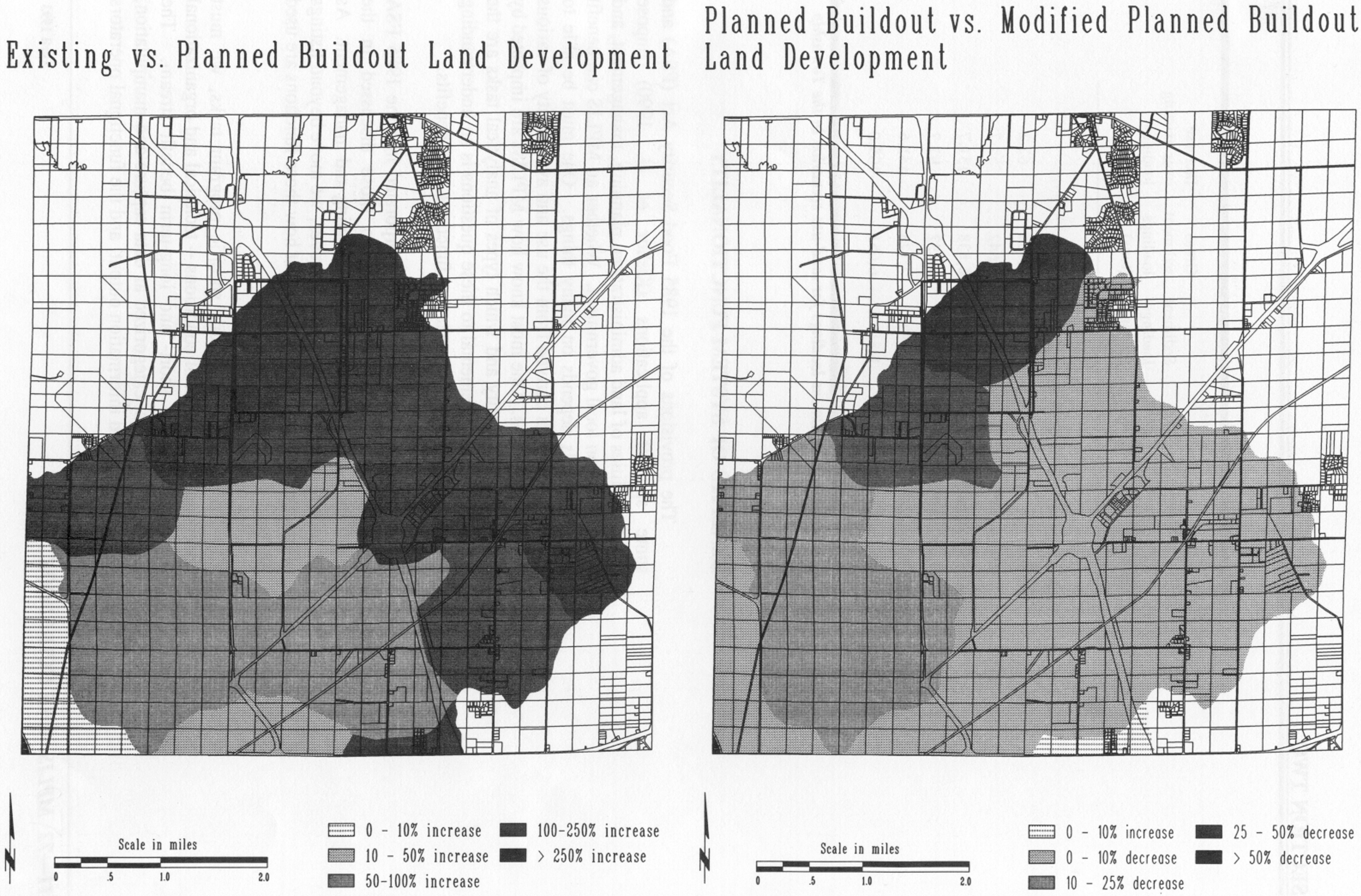


Figure 11-28: GIS approaches to nonpoint pollution assessment.

Scenario	Sediment loadings (lb/acre)	Gross sediment loadings (tons)	Increase over existing loadings (%)
Existing	1,513	2,951	
Planned	1,624	4,785	62.2
Modified Planned	1,671	4,642	57.7
Plan Buildout	1,846	6,838	131.7
Modified Plan Buildout	1,781	5,832	97.7
Zone Buildout	1,883	7,128	141.6
Modified Zone Buildout	1,816	6,051	105.0

Table 11-12: Annual sediment loadings for land-use scenarios in the Township of Burke.

BENEFITS OF SYSTEM FUNCTIONALITY

The provisions of the 1985 Food Security Act (FSA) and some spin-off applications (Kishor et al. 1990) impose responsibilities of land administration, planning, management, and policy tasks on local government. Whether an MPLIS can benefit these demands depends on many things. One must be able to assess the benefits derived from the use and availability of various GIS/LIS functions. One must know how MPLISs are impacted by GIS/LIS functionality and which types of analytical tasks are the most beneficial. Elemental to these questions is an understanding of the relationship between tasks, functions, and benefits.

The analytical applications incorporated into the 1985 FSA example are conceptually similar to those discussed in the application on soil erosion control planning and management. As we look at cost/benefit streams, however, we move beyond listings of functionalities and begin to look at how those functions are used for various tasks.

To address the various specific program tasks, we must understand the full set of conditions -- technical and organizational -- that impact the short- and long-term benefit stream. The technical functions, categorized as data capture and manipulation, data analysis, and information output, and the functional operators actually used must be considered. These technical functions must be regarded in conjunction with two institutional conditions critical to the full and successful exploitation of this vast set of GIS/LIS functions (Table 11-13). These institutional conditions consist of the organizational changes required in the work place to maximize the use of the various functions and the institutional arrangements needed to ensure that agencies establish effective communication channels. Organizational change and adaptation and institutional awareness are critical conditions to assure that the full stream of benefits is obtained.

The expanded matrix (Table 11-14) lists the technical and organizational functions in the first column for each task undertaken in Dane County and includes a description of each task in terms of the actual elements involved. The text describes the character of the benefit derived from incorporation of the various functions and lists the type of benefit derived from the set of functions utilized. For purposes of this discussion three categories of benefits are identified: efficiency, an overall measure of accomplishing the tasks faster; effectiveness, an increased capacity to perform tasks previously infeasible; and equity, an indication of overall fairness and impartiality through uniform treatment (Kishor et al. 1990).

Obviously, there is a correlation between the type of tasks involved and the functions utilized. It is therefore important to use this particular case study of the 1985 Food Security Act in the context under which there results were conducted. Important findings have been revealed.

- o Potential benefits are highly dependent upon the organization and institutional conditions in which the technology is employed. GIS/LIS functions make it possible to accrue benefits, but their full employment will eventually depend upon how quickly and effectively institutions adapt.

- o Most benefits would not be obtainable without the access to a variety of GIS/LIS functions, even though there is not necessarily a direct causal relationship between functions and benefits.

- o The technology *per se* cannot ensure equitable results, but because analyses can be conducted more efficiently it becomes possible to conduct an analytical operation

Table 11-13: List of GIS/LIS technical functions and institutional conditions.

Technical functions			Occurrences
1.	Data Capture and manipulation		
	1.1	Data capture through digitizing or scanning	6
	1.2	Data quality checks such as completeness and logical consistency	6
	1.3	Compact storage and flexibility through automation	5
	1.4	Data transformation from one coordinate system to another	4
	1.5	Data presentation at multiple scales	3
	1.6	Map Project changes	3
	1.7	Increased coding and classification efficiency	4
	1.8	Easy update of database	5
	1.9	Increased positional accuracy because of Global Positioning System	3
	1.10	Increased positional accuracy because of orthophoto quarter quadrangles	3
2.	Data analysis		
	2.1	Full relational data management capability	15
		2.1.1 Sorting and indexing	15
		2.1.2 Selective retrieval of data by logical or spatial criteria	17
		2.1.3 Full spreadsheet analysis	15
		2.1.4 Attribute merging by combining two or more database files	15
		2.1.5 Programming to expedite tedious operations	17
	2.2	Spatial data manipulation analysis	
		2.2.1 Buffering points, lines and polygons	9
		2.2.2 Combining two or more maps to create new maps--e.g., polygon overlay	10
		2.2.3 Accurately measuring occurrences, distances, and areas	7
	2.3	Data conversion for viewing/analysis purposes--e.g., contours to TIN 4	
	2.4	Modeling	6
	2.5	Performing "what if...?" analysis	3
3.	Information output		
	3.1	Immediate graphics display	5
	3.2	Customized hardcopy maps made quickly at varying scales	13
	3.3	Tabular display of attributed	14
	3.4	Easy generation of customized attribute reports	14
Institutional Conditions			
4.	Organizational changes		
	4.1	Encouraging use of new methods	2
	4.2	Hiring new, knowledgeable staff	1
	4.3	Training current staff	1
	4.4	Commitment of upper level management and elected officials	1
5.	Institutional arrangements		
	5.1	Data-sharing (multiple access of shared data by participating agencies)	5
	5.2	Data-custodianship	2
	5.3	Regular meetings for reporting and planning	2
	5.4	Cooperative agreements and memoranda of understanding	2

TABLE 11-14: CONSOIL PROGRAM BENEFITS OF GIS/LIS

User Interfaces

Command driven user interface
Pull-down or pop-up menu user interface
Icon-based user interface
Batch programs or command files for series of functions
Macro language or shell scripts for creating new commands
Source code or object code library for user program development
Tutorial or other method for self-instruction
An "undo' command to restore conditions prior to command
Recall of previous command(s) for re-execution
Logging of commands or operations
Soft error recovery
- user friendly error messages
- restore data files to original form
- remove scratch files

Data base management

Linkage of geographic data with attribute DBMS
Facility for entering data quality information
Facility for recording data lineage
Facility for tracking transactions or updates
Access to attribute data
- direct - by attribute identifier
- direct - by selected geographic feature
- through relational key
- by natural language or SQL instructions

Ability to create, view, and manipulate meta data
Database operations
- sort tabular or graphic files by attribute or location
- calculate new values by arithmetic or logical expressions
- relate data files by common unique identifiers
- define rules governing behavior of data elements
- create, store, retrieve, and generate standard reports

Provision for organizing files by project
Generation of status reports on content and status of data base
Capability to add data files without regard to size or scale
System security
- password access protection
- electable read only or read/write access for different users

Computer network operation
- access common data file from file server
- data check out/check in procedure

Geographic Data Automation

Manually digitize two-dimensional point, line, or polygon data
'Snap-to' previously digitized features
Photogrammetrically digitized data incorporation
Coordinate geometry: protract lines, angles, and curve, intersect lines (create nodes), bisect angles, locate tangents, least-squares traverse adjustment, store curve as radius, arc endpoints, or center point, arc endpoints, offset parallel lines
Manually encoded raster (cellular) data: raster editing, thresholding and line thinning, raster to vector conversion
- scanned map data - raster
- scanned photographic or satellite data

Topological structuring
- manual assembly

automatic (batch) assembly of polygons from lines
automated calculations of area, length, perimeter

Data Editing and Error Correction

Attribute data association
- associate multiple attributes with geographic features
- assign attributes
- completeness check
- attribute range or value checks
- attribute format checks

Select features
- by pointing
- based on attribute value

Insertion or deletion of selected geographic features
Cut and paste' from update file
Interactive movement of individual points, lines, or areas
Interactive graphic annotation editing
Automated topological error reporting

Terrain and other 3-D Surface Representation

Contours
Regular gridded Z-values (digital elevation models)
Triangular irregular network (TIN)
Constrain contours by specifying barriers
Calculate cut or fill volume
Determine drainage networks or floodplains
Determine ridgelines or watershed boundaries
Determine viewsheds from user specified points
Compute slope and aspect values
Plot planar geographic features (terrain drape) over
  2.5 D net, wireframe, or contours
Plot geographic features or perspective view
  with shaded relief and hidden line removal

Import/Export

Arc/Info
AutoCad

DEM
DLG
ERDAS
ETAK
GIRAS
GRASS
Intergraph
MOSS
TIGER
Spatial Data Transfer Standard (SDTS)
etc.

Data display and analysis

Data Retrieval - select and display
- by theme or layer
- within window specified by coordinates or reference map
- within window specified by on-screen digitizing -
- by feature names or groups of names
- by logical and Boolean retrievals on attributes

List attribute values of selected features
Report location of feature by pointing
Report straight-line distance or length by pointing
Report along-line-feature (network) distance by pointing

Data Restructuring
- raster to vector conversion
- vector to raster conversion
- map tile or sheet appending
- automatic edgematching
- line thinning or smoothing

Data Transformation
- planar transformations
- 'rubber-sheeting' planar transformations
- extract control point coordinates from master file
- incorporation of USGS/NOAA projection package
- incorporation of NOAA-NGS NadCon datum conversion

Overlay
Graphic superimposition
Topological overlay
Sliver removal
Cross-tabulation
Area weighted average

Networks
- Maintain line and node attributes
- Determine optimum path through network
- Determine optimum route for distribution through network
- Calculate optimum allocation or collection zones

Other Geoprocessing
- Buffer
- Proximity report
- Nearest neighbor
- Automated address matching
- Adjacency

<u>Data Display and Information Product Creation</u>

Data Display
- Generate graphic displays (on screens, plotters, etc.)
- Display vector data with raster (image) backdrop

Information Product Creation
- Compose products interactively
- Compose products with command files or map templates
- Store, retrieve, and re-display compositions
- User specified scale, orientation, map size, location on sheet
- Display point, line, and polygon data sets
- Display map features: neat lines, grid lines graticules
- Create and position: scale bar, legends or keys, north arrow, map titles, logos, single or multiple line text
- Interactively position map elements
- Ability to select point symbols, line types, and area fill patterns
- Ability to create, name, store, and select new point symbols, line type, and area fill pattern tables
- Ability to assign by attribute, selection or lookup table
- Automatically position text at pre-specified point location
- Ability to specify individually for any text string: font, case, size, spacing, color, angle, curvature

not previously economically possible. These functions empower the user to do analyses that had previously been manual and therefore technically impossible. This new empowerment provides the opportunity to implement policy in a more equitable manner than ever before.

- o Data analytical functions exist in the context of additional GIS/LIS functionality requirements. This includes the need to capture and convert data into a digital form prior to applying any analytical functionality.

- o Just as obvious is the need to portray the analytical and informational results graphically. The power and flexibility of GIS/LIS graphic functionality also expand the benefit stream. Being able to convert complex tabular data and calculations into graphic displays further increases the power of the tool and the resultant benefit stream.

- o In a multipurpose environment a full range of analytical functions is needed, even though some analytical functions dominate as a result of the variety of program tasks that require attention. In the Food Security Act case study, an excellent example is the "full relational data management capabilities."

Access to a robust array of functionality also expands the potential for an increased benefit stream; it therefore also increases the potential for successful and useful implementation of the overall technology and assists in the bringing about of institutional commitment.

SUMMARY

Computerized information technologies in the form of multipurpose land information systems coupled with relevant analytical functions offer land planners, managers, and policy analysts a very powerful method by which to plan, manage, and understand the natural resources of rural America. The technology has sufficiently matured; data bases are being developed by local, state, and Federal agencies that are useful to planners, managers, and policy analysts; and societal mandates such as the 1985 Food Security Act and the 1990 Food, Agriculture, Conservation, and Trade Act are requiring the full employment of analytical techniques. These mandates, MPLIS, and expanding analytical functionality are making Manning's dream -- the ability to connect people with place -- become a reality.

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12 THE BASE MAP

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INTRODUCTION

Earlier, in Chapter 2 of this Guidebook, an Introduction to Mapping Concepts was presented. In this chapter we focus on a particular aspect of mapping, base maps. In discussing base maps we consider the purposes for which base maps are developed and used, discuss the basic approaches that are used to construct base maps, examine digital mapping and the advantages it has for base mapping purposes, and suggest several factors to be considered when developing a base mapping program. Therefore, the primary focus in this chapter is on what a base map is, why a base map is needed, and how one can go about classifying base maps and their contents. Later, in Chapter 19, how a base map is constructed and maintained is discussed in some detail.

DEFINITION

A base map can be defined in several ways, particularly given the advent of widespread computer mapping and other computer-generated graphics materials. For example, Robinson, et al., using a traditional cartographic view, suggest that a base map is "a map containing geographical reference information on which attribute data may be plotted for purposes of comparison or geographical correlation" (Robinson, et al., 1984, p. 517). Robinson notes that the view of the map maker and map user often vary and indicates that one observer has suggested that "Maps have many functions and many faces, and each of us sees them with different eyes" (Skelton 1972, p. 31).

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Another source defines base map as "a map on which information may be placed for comparison or geographical correlation" or as "a map from which other maps are prepared by the addition of information. In particular, a planimetric map used in the preparation of topographic maps" (NGS 1986, p. 142).

Yet another source defines a base map as the graphic representation at a specified scale of selected fundamental map information; used as a framework upon which additional data of a specialized nature may be compiled (American Society of Photogrammetry 1980, cited in NRC, 1983, p. 37). In local government, the term base map has been applied to a wide variety of maps, ranging from large scale parcel maps to small scale maps showing streets, railroads, rivers, and other geographic features. In order to more clearly understand exactly what a base map is, we first turn to the purpose for and uses of such base maps.

PURPOSE AND USES OF BASE MAPS

Earlier we have noted that to be able to process, manipulate, analyze, and display land (spatial) information, it is absolutely necessary that an accurate framework be in place as a frame of reference. As is noted throughout this Guidebook, a key, required component of such a frame of reference is a geodetic network. This component was also stressed by the National Research Council (NRC) in their studies on the multipurpose cadastre in the early 1980s.

However, while a geodetic reference system is a required component for an effective MPLIS, such a framework is not sufficient by itself. In order to facilitate system use (i.e., to ensure the "user-friendliness" of the MPLIS), it is also necessary that a "base map" be part of the system. Such base maps, whether in traditional hardcopy or digital form, are a key factor in being able to relate map (graphic) data and attribute data, the two major classes of data found in all MPLISs. In short, a base map should contain a minimum set of data that is useful to, and will be used by, a large set of MPLIS users. These data, like the geodetic layer, can be used to (1) relate objects on a single layer to other objects on that layer, (2) relate objects on two or more different layers, and (3) locate various data layers in space (i.e., based on a common geodetic reference system). In short, a base map should contain enough data to allow MPLIS users to orient themselves to the data in the base layer, as well as to integrate data from two or more layers that may be used for any particular analysis.

Huxhold articulates this purpose for base maps as follows: base maps "contain points, lines, polygons, symbols, and text in a spatial context that allows a visual understanding of how ... cartographic objects are related to each other" (Huxhold 1991, p. 186). In an MPLIS, "a base map contains the cartographic information that is common among all the different users of maps" (ibid.).

TWO TYPES OF BASE MAPS

There are several ways to classify base maps and one of the most useful ways is by their information content. "The base map consists of either cadastral information (the legal identification of features), or planimetric information (the physical identification of features), or it may consist of a combination of both cadastral and planimetric information" (ibid.).

Since there are major differences between cadastral and planimetric information, the decision about which type of information to use as the basis for a base map is a significant one. This decision will affect both the use of the MPLIS as well as the cost of building (and maintaining) the base map itself. The differences result because cadastral maps are based upon legal definition of land parcels and planimetric maps are based on physical features that can be seen on the land. Because of the differences in these two major feature classes, these two types of maps often disagree as to the location of a common feature.

PLANIMETRIC APPROACH TO BASE MAPPING

A planimetric base mapping approach has been the most common type of base mapping in many parts of the United States. This approach is based on the physical features that can be seen on the ground and recorded on maps. Therefore items that may be included on planimetric maps include "curb lines, roadways, sidewalks, street intersections, rivers, lakes, trees, manhole covers, fire hydrants, buildings, bridges ... fence lines" (Huxhold 1991, p. 186). The items included on planimetric maps "can be identified during field surveys or on photographs taken from airplanes" (ibid.).

The amount of detail collected from aerial photographs for inclusion in a planimetric (or line) map varies, depending on such factors as the uses the base map will serve, the financial resources of the agency building and maintaining the map, and other resources available. Therefore, one jurisdiction might include only roads, railroads, and major lakes and rivers. Other jurisdictions, with more resources and more planned uses for base map information, might include the entire list of information proposed by Huxhold in the list above.

Many base maps include information on elevation. For example, Chapter 19 describes the use of the stereo digitizing process, whereby ground elevations are obtained from aerial photographs to produce topographic maps. The resultant elevations are then displayed on a planimetric (base) map as elevation contour lines (i.e., lines connecting points of equal elevation).

One of the most common base maps in use in the United States is produced by the U.S. Geological Survey (USGS) in the U.S. Department of the Interior. These maps are produced in a variety of scales ranging from 1:24,000 to 1:2,000,000. However, jurisdictions desiring digital versions of USGS maps should be aware that, generally, only hardcopy versions are available for maps with scales greater than 1:100,000. Additionally, the USGS update cycle is relatively long, which means that jurisdictions wanting more frequent updates than USGS can provide will need to budget their own resources for such updates. For base map purposes, many jurisdictions rely on the 1:24,000, 7.5 minute USGS quadrangle maps that contain natural resource inventory, land use, and transportation layers. Larger scales (e.g., 1:500 or 1:600, up to 1:9,600 or 1:10,000) are required for many base map uses in urban areas.

Oneida County, Wisconsin, used the planimetric approach to base mapping. A description of the Oneida County base mapping program can be found in Appendix 12-1.

CADASTRAL APPROACH TO BASE MAPPING

The cadastral approach to base mapping focuses on the legal identification of features (as opposed to the physical identification of features in the planimetric approach). Because so much local government activity involves cadastral (parcel) data, many jurisdictions rely on the cadastral approach for base mapping.

Cadastral records contain data on ownership, taxation, and the delivery of a variety of public services ranging from utilities to health and public safety. The tax and ownership parcel are typically at the heart of a cadastral base map system.

Records on ownership and other legal interests in land parcels incorporate a wide variety of data. These records include ownership deeds, mortgages, liens, pending court actions, special assessments, zoning, rights-of-way, and easements (Huxhold 1991, p. 187).

To build and maintain an accurate cadastral base map requires data on the location and shape of each parcel, as well as the relationship of each parcel to other parcels. Further, as suggested above, many legal claims on the parcel are derived from local government powers of zoning, taxation, and similar legal authorities. This means that an accurate cadastral base map must draw on many records including deeds, tax descriptions, plat and subdivision maps, a variety of legal documents, indexes to legal documents in a variety of offices, and indexes to maps used for taxation, planning, etc. Because of these complexities, many jurisdictions build their initial cadastral base map by scanning existing tax parcel maps. A second, much more difficult, but much more accurate approach is to use computer driven coordinate geometry (COGO) programs that create digital records directly from legal descriptions recorded in the recorder or register of deeds office.

The 1980 NRC report on the "Need for a Multipurpose Cadastre" referred to base maps as "conventional photogrammetric line maps or orthophoto maps" (NRC 1980, p. 53). The NRC identified the base map, one of the five key components of the multipurpose cadastre, as consisting solely of the mapped data representing the physical features on the land. However, the NRC definition also included a cadastral overlay layer that links the base map, through the geodetic reference framework and coordinate system, to parcel maps, parcel descriptions, parcel indexes, location identifiers, and related land data files. Thus parcel (or cadastral) information, while not included on the recommended NRC base map, is closely linked to the planimetric base map through the reference framework.

The cadastral approach to base mapping has been used by Marion County, Oregon, in their Geographic Land and Data System (GLADS) (Kjerne 1984, p. 234). In GLADS, hardcopy maps are converted to a digital version and "stored on disk as a series of separate drawing files, each of which covers a section, quarter-section, or quarter-quarter-section at different scales. This information will eventually be merged together to form ... a 'continuous digital map' ..." (ibid.).

COMBINING THE PLANIMETRIC AND CADASTRAL APPROACHES

There are jurisdictions that use a combination of planimetric and cadastral information to build their base map. This combination approach is useful for jurisdictions that do not have a parcel map system, or where the existing maps are inaccurate, out-of-date, or otherwise unsuitable for digitizing or scanning (Huxhold, 1991, p. 192). "In these jurisdictions, planimetric maps are created from orthophotographs, and the parcel boundaries are added from the legal descriptions of the parcels, using reference points common to both sources. These references are usually physical features identified on the orthophotograph and also referenced in a parcel's legal description: the centerline of a street, a railroad, the shoreline of a river or lake, and other physical entities that, while too small to see on an aerial photograph, have been temporarily marked with a larger object (known as a target). Locating parcels in relation to these common reference points is often difficult and, in a densely populated area, very time-consuming because of the large number of parcels and the small number of reference points common to both map sources" (ibid.).

The process necessary to combine cadastral and planimetric data for a base map is not an easy one. North Carolina has a state program to assist counties in developing such a combination base map. Don Hollaway, then director of the North Carolina base mapping program, described the following steps needed in such an effort.

1. Create a planimetric base map from orthophotographs.

2. Conduct research in the Register of Deeds office, for every deed that is included in a particular map.

3. Input all boundary information from the deeds into an automated plotter.

4. Use the automated plotter to compute and generate a to-scale figure of each parcel.

5. Transfer these parcel drawings to a work copy of the base map.

6. Reconcile any gaps and overlaps of adjoining parcels. (These checks include such things as reference to use lines (fences, roads, streams) and field checks.)

This latter step is a most difficult one. Eunice Ayers, the former Register of Deeds in Forsyth County (one of the first counties in North Carolina to participate in the program), described the problem as follows.

"The most difficult single phase in the [MPLIS] project has been to complete the production of the graphic base (map)--identifying and resolving discrepancies between the graphic parcel descriptions digitized from tax maps and orthophotographic base maps. This process of rectification has been long, difficult, and frustrating. --- In compiling the land records, it is clear for the first time what mistakes and errors have existed in those records for years" (Ayers 1984, p. 298).

DIGITAL MAPPING

As we have noted throughout the Guidebook, it is not absolutely necessary for an MPLIS to be automated to function. Many improvements in land information systems can be made in a manual form. However, there are also many instances when major benefits of an MPLIS accrue primarily if the system is in an automated mode. Development of base maps is one of the areas where automated, digital methods are preferable.

One reason automated maps are preferable is that they provide an opportunity to shift our thinking away from hardcopy maps and to information arranged spatially in general. Any data that can be displayed spatially can be included in a digital data base. By storing these data in layers, it is also possible to select only those items necessary for any particular display, whether on a cathode ray tube (CRT) or as a plotted "map" on paper, mylar, or other print media.

A second major advantage of digital map data storage is the relative ease with which these data can be updated compared to hardcopy maps. Hardcopy maps are very often out-of-date as soon as they are produced. Also, to make corrections and updates requires reproducing copies for all users, or correcting each hardcopy map in existence that contains the data in question. On the other hand, a digitally based map can be updated as often as appropriate, even on a daily basis. Once the change is made to the digital data file, all subsequent users of the data base will have the latest information at their finger tips.

A third advantage of digital maps is the significant amount of digitally mapped data that already exist. Further, digitally mapped data resources are likely to continue to expand at a rapid rate. Examples of a few digital data bases that already exist provide an indication of the potential of this approach to mapping in general and base mapping in particular.

The USGS produces digital cartographic base data known as Digital Line Graphs (DLGs) and distributes them through the National Digital Cartographic Data Base. Large-scale DLG data are generally derived from USGS 1:20,000-, 1:24,000- and 1:25,000-scale topographic quadrangle maps. Intermediate-scale DLG data are derived from USGS 1:100,000-scale quadrangle maps. (Large-scale and intermediate-scale as stated here are as used by USGS. For most MPLIS developers and users, both of these scales (1:24,000 and 1:100,000) would be characterized as small-scale.) Large- and intermediate-scale DLG data are collected in nine separate categories: hypsography, including contours and supplementary spot elevations; hydrography, including flowing water, standing water, and wetlands; vegetative surface cover, including woods, scrub, orchards, vineyards, and vegetative features associated with marshes and swamps; non-vegetative features, including lava, sand, and gravel; boundaries, including state, county, city, and other national and State lands such as forests and parks; survey control and markers, including horizontal and vertical positions of third-order or better; transportation, including roads and trails, railroads, pipelines, transmission lines, and miscellaneous transportation features; manmade features, including cultural features such as buildings; and US Public Land Survey System (PLSS), including township, range, and section information. Although collection of all DLG categories for the entire nation is far from complete, significant numbers of DLGs are available. For 1:24,000 DLGs, USGS has focused its collection efforts on the PLSS, boundaries, transportation, and hydrography, although a thousand or more DLGs have been produced for every category. At the 1:100,000 scale, nationwide coverage is currently available for hydrography and transportation. Nationwide 1:100,000 coverage for PLSS, boundaries, and hydrography is scheduled to be completed by 1995.

The TIGER (Topologically Integrated Geographic Encoding and Referencing) system is an integrated data base containing all of the spatial data needed to administer the 1990 Census of Population and Housing. All statistical and reference maps for the 1990 Census were computer generated from the TIGER data base. The TIGER files contain data from three primary sources: (1) line segment produced maps from the USGS, (2) existing DIME files (DIME was the geographic base file created for the 1980 Census of Population and Housing), and (3) geographic area relationship files used for tabulating the 1980 Census. These three sources were merged into one integrated spatial data base. The TIGER data base is being used for reapportionment of election districts throughout the country. While it is not a LIS or GIS by itself, it does provide a data base that can be useful in many GIS/LIS applications.

Many of the existing digital data bases are of small scale. For example, the TIGER data base was built from the 1:100,000 USGS map base and is therefore not suitable for use in cadastral-type base maps. However, the TIGER line files are available for each of the 3,000 plus counties in the U.S. The TIGER file contains geographic features, such as roads, railroads, and rivers, as well as census block and tract numbers, address ranges, and latitude and longitude for each point. Therefore, these data are often adequate where small scale maps are relevant, such as for planning and resource management.

Digital base map data are sometimes available from other agencies or companies operating within a jurisdiction. Public to private base map sharing has been accomplished in Milwaukee, Wisconsin, with the city providing their cadastral base map to the utility, thus saving the utility the cost of initial compilation of such a map. In other cases, "private companies also provide digital base maps to local governments on a commercial basis. These files are usually byproducts of the primary service they provide: producing maps, providing GIS software and services, or converting maps to digital form for other organizations" (Huxhold 1991, p. 261). Whatever approach is used, the cost of developing a digital data base map depends upon: which features are converted (e.g., contour lines cost more than curb lines) and the accuracy of the placement of the features (i.e., the higher the accuracy, the greater the cost).

DEVELOPING A BASE MAPPING PROGRAM

In developing a base mapping program, there are a number of factors to consider. These include currently available spatial data, in both hardcopy and digital map form, financial and personnel resources that can be allocated to the process, the scale(s) of products that are to be produced, the accuracy requirements of the system users, the functions that the MPLIS, of which the base map is a part, are to address, and the subject matter of the various data layers that are to be included in the MPLIS. Several of these factors are introduced in Chapter 2. Others are addressed in Chapter 19. Chapter 19 also addresses specifics of base mapping programs, including development of plans and specifications, phases of the program, paneling and ties to the geodetic control framework, ground control surveys, stereo compilation, and producing a finished product. Alternative methods of producing base maps are discussed as well.

SUMMARY

Base maps are a critical component of an MPLIS because these maps record the geodetic, planimetric, and cadastral references to which the many users of the system will add their own special purpose data for display and analysis. Base maps are also important for the users because they can provide a continuously updated record of current geodetic, planimetric, and cadastral information as changes occur over time. Therefore, since the quality and use of data in the system rely heavily on the base map, these maps should be given major attention when constructing an MPLIS. Also, since the cost of mapping can be substantial, careful attention to the true needs of system users and alternative sources of data that can be used to construct and maintain base maps are equally important. As one of the key components of the MPLIS, planning and investments up front can be expected to yield major benefits in the future.

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APPENDIX 12-1
ONEIDA COUNTY CASE STUDY

INTRODUCTION

Oneida County, located in north-central Wisconsin and created in 1887, covers a total area of 779,000 acres of which 74,000 acres are water. There are 34 1/2 survey townships encompassing 1,242 Public Land Survey System (PLSS) sections of land. The County maintains a resident population of approximately 32,500, though it lists 52,200 parcels on the assessment role. This discrepancy is due to the large number of non-resident land and homeowners that visit the County for summer and winter recreational purposes.

Like many other counties in the State of Wisconsin, Oneida County is moving forward in the automation of its land records using GIS/LIS technology. A Land Records Committee was created in 1987 as a standing committee of the County Board to provide guidance on the development of a modern, computerized, parcel-based land information system. An early initiative of this process involved the creation of a base map to provide the foundation for consistent and accurate mapping of county records, including tax parcels, hydrography, soils, the transportation network, etc.

BASE MAP CHOICE

Oneida County considered a number of options to build a base map suitable for their mapping needs. They finally decided to build a digital planimetric base map, stereo digitized from aerial photography referenced to the state plane coordinate system that could be related to the PLSS. County officials felt that a photographic base map referenced to good ground control would allow them to accurately define the relative spatial location of landscape features and analyze the spatial relationships between real property boundaries and other land related data. Due to the County's dense forest cover, numerous lakes, streams, rivers, and irregular transportation network, aerial photography was the quickest and most economical means to construct the planimetric base map.

CONTROL FRAMEWORK

In 1989, the County acquired 1:20,000 photography to support the production of its digital planimetric base map. Leaf-off photography was obtained in order make detection of water boundaries, roads, and buildings easier. A 1:20,000 flight scale was chosen so that 1:2,400 and 1:4,800 scale map production that meets National Map Accuracy Standards could be supported. Prior to the flight, 55 ground stations were selected, monumented, witnessed, paneled, and observed using Global Positioning System (GPS) technology to provide horizontal control for the photography. The selected stations were spaced at approximately two-mile intervals along the County boundary and eleven-mile intervals in the interior. This spacing was dense enough to support the planned flight path and photo tiling strategy. The 55 GPS stations were observed with a 1:250,000 or better precision ratio and meet or exceed Federal Geodetic Control Committee (FGCC) second-order, class I standards. Elevation values (z) were also obtained during the GPS observations to provide vertical control, however these values do not meet FGCC standards. The 1990 total cost of the GPS surveys was $30,000 or approximately $545/station.

Nine hundred PLSS survey corners were also paneled prior to the flight in order to relate PLSS to the aerial photography and to derive approximate coordinate values for the corners during analytical processing of the photography. This was done in order to allow creation of a simple land net to support resource management and land planning purposes. On average, these photographically derived PLSS corner coordinates are correct to within 1.5 feet. To support future parcel mapping activities, survey-accurate coordinates will be determined for all the PLSS corners.

BASE MAP CONSTRUCTION

In order to construct a digital planimetric base map for the County, the 1:20,000 photography and GPS control could have been used to create mylar orthophotograph maps, from which the planimetric features could then be digitally derived. However, production of the hard copy orthophoto would have been an extra, costly step. The County decided to pursue stereo-digitizing instead, where base map features were digitized directly from film diapositives. The method of stereo-digitizing provided two benefits:

(1) planimetric base information, registered to a reference system, could be acquired for virtually the same cost as mylar orthophoto production;

(2) better positional accuracy of base features could be achieved (5-10') in comparison with orthophoto map digitizing (12'+).

Features derived from the diapositives included:

* geodetic reference system (paneled GPS stations)
* hydrography (i.e., lakes, rivers, streams, ponds, reservoirs)
* transportation (i.e., roads listed in the County Emergency Response Inventory, railroads, logging roads, airports, bridges)
* building footprints
* other cultural features (dams, major transmission lines, pipelines, sub stations, etc.)
* land net boundaries (PLSS) based on paneled corners
* annotation (textual information concerning map features)

As a special case, wetlands were not compiled from the photography due to the rigorous classification and delineation standards required by the Wisconsin Department of Natural Resources (WDNR). It was decided that wetlands would be automated at a later date in cooperation with WDNR, following their mapping and coding guidelines.

Oneida County entered into a contract with a private firm to complete the stereo-digitizing. Since the County had earlier selected ARC/INFO as its in-house Geographic Information System (GIS), it was important to find a contractor that was familiar with the software data model and that could deliver the appropriate format. During the bidding process, a number of contractors offered the capability to compile base features in one format that could be converted to the County GIS format. County staff chose to work with a vendor that could deliver in the ARC/INFO data format to avoid potential post-processing headaches that often accompany data conversion efforts.

Stereo-digitizing of base map features included not only the compilation of spatial information, but also coding of features following a predetermined tabular data base design strategy. Oneida County has been party to a multi-county Wisconsin consortium (LOCALIS Project) evaluating GIS data base design alternatives, specifically with regard to feature codes. Consortium discussions have been driven by the need for standardization among Wisconsin counties and compatibility with in-place federal and state data bases. For example, the U.S. Environmental Protection Agency and WDNR both maintain independent waterbody identification schemes for in-house purposes; however, coordination with County spatial data base development activities is also imperative. The LOCALIS Project County Consortium is attempting in part to meet that need.

BASE MAP MAINTENANCE

Natural features of the base map are not expected to change significantly over time and subsequently will need little revision. Natural features include lake shoreline boundaries, river banks, etc. Cultural features will be subject to more change and require a mechanism for update. Current subdivision regulations and zoning ordinances are a mechanism to track new or destroyed buildings and new road locations. Alterations of the administrative boundaries (i.e., municipal annexation), are usually filed in the Register of Deed's office. Other contributing parties will include town assessors, local fire departments, utilities, school districts, and city, state, and federal agencies. Many of these parties will likely be using the planimetric base map and other digital layers derived from the base (i.e., tax parcels) to meet their legal mandate and/or public service responsibilities. This common spatial and tabular data base will hopefully facilitate the inter-departmental and organizational communications needed for regular maintenance.

For additional information, contact:

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13 THE PARCEL MAP

Earl F. Epstein and D. David Moyer

INTRODUCTION

This chapter is a discussion on parcel maps. In this discussion we consider:

- purposes for which parcel maps are created and maintained,
- the basic approaches that are used in the construction of parcel maps, and
- possible factors that are important in the design and implementation of a parcel mapping program.

Other chapters related to parcel mapping that are relevant to the discussion presented here include:

- Chapter 2 Introduction to Mapping Concepts
- Chapter 12 The Base Map
- Chapter 19 Mapping: Methods and Procedures

As in Chapter 12 on Base Mapping, the thrust of this chapter is on what a parcel map is, why a parcel map is needed, and how one goes about classifying parcel maps and their contents. Readers will find specifics on HOW to construct and maintain parcel maps in Chapter 19, where such matters are discussed in some detail.

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DEFINITION

A parcel map requires a fundamental unit - a parcel. This unit of land, the parcel, becomes the building block for information management, including information about land rights and interests. The parcel is also used in maps as the representation of the units themselves.

There are many land rights and interests, each right or interest representing a stick in the bundle of legal interests in a community. A parcel is an unambiguously defined unit of land within which a bundle of rights and interests are legally recognized in a community. A parcel encloses a contiguous area of land for which location and boundaries are known, described, and maintained, and for which there is a history of defined, legally recognized interests. The concept of a parcel has been defined as follows:

"A parcel is a continuous area of land described in a single description in a deed or as one of a number of lots on a plat, separately owned, either publicly or privately; and capable of being separately conveyed. For ease of indexing data, a segment of a street, highway, railway right of way, pipeline, or other utility easement may be treated as though it were a parcel" (Moyer and Fisher 1973). Determination of parcel boundaries on the ground defined in this way requires a sorting out of various other interests in land that are legally recognized. These parcels may or may not be coterminous. Generally, but not always, the primary interest is land ownership, as commonly understood, associated with those rights and interests that may be acquired and transferred.

Normally a parcel map represents the parcels from a specified area such as a region, county, township, Public Land Survey System (PLSS) section, municipality, subdivision, or some other defined area. The parcel map includes the boundaries of the land interests for these parcels. The parcel map may be called by a variety of names, including plat map, assessor's map, tax map, or cadastral map. Each map represents a compilation of land records specific to the particular map. However, the content, symbology, scale, accuracy, currency, completeness, and consistency vary widely among these common, specific parcel maps.

PURPOSES AND USES OF PARCEL MAPS

Parcel maps were developed and are used for a variety of purposes. These include:

1) an index to data and information about the parcel,

2) a representation of the boundaries of several related parcels, and

3) a basis for land-related decisions.

For example, tax assessor parcel maps are often used as indexes to assessment files, and as a means to visually display information to citizens about their particular lot. Surveyors prepare plat maps to denote the shape, relationship, and location of groups of parcels in a plat, as well as individual ownership parcels. Governments, particularly at the local level, use parcel maps to plan and manage the provision of a wide variety of services. Therefore, parcel maps are extremely useful, widely used, but still not universally available in all jurisdictions.

In its simplest form, a parcel map depicts in graphical form the boundaries of those particular sets of interests which are included in the bundle of rights for the land parcels.

For the common set of interests associated with land ownership, the boundaries are often described in terms of metes and bounds. However, existing parcel maps, compiled for a variety of purposes, and relying upon information whose sources are often not clear, make the compilation of parcel maps for an MPLIS a demanding task. The following are examples of the problems and decisions a parcel mapper typically faces as parcel maps are compiled, updated, and used.

1. Division and combination of parcels: One or more parcels that do not share a boundary line for one purpose are sometimes treated as a single parcel for other purposes. For example, two parcels which originated in separate ownership but are now owned by one person may be treated as one for purposes of tax billing.

Another example involves subdivision and re-subdivision of parcels. Parcel maps often show subdivided lots even when two or more must be combined to make a buildable lot, but some jurisdictions do not require a recorded re-subdivision for this combination. Alternatively, the map may show the re-subdivision as originally divided, with a tie bar indicating the association.

A third example involves lot combinations and splits. Owners may request the assessor to combine two lots, or split one lot into two, without any other action or survey recorded. In all of these examples, parcels which at one time were distinct are now combined or divided.

2. Easements: The treatment of easements on parcel maps varies widely. Some parcel maps show publicly held easements; some show any easement that affects assessed value; some show recorded easements only; and some do not show any easements at all.

For example, drainage easements and other areas that are dedicated to the local government as part of a subdivision may be indicated on the parcel map. Other interests from the "bundle of rights" such as zoning and tax districts are often treated as a separate map (or overlay), or separate attribute file. Many easements have never been recorded and even today, many jurisdictions do not always require their recordation.

3. Inconsistent descriptions: Some descriptions refer to land corners. Others refer to offsets from an engineering base line which are more likely to be tied to geodetic control monuments. Some refer to physical features, such as the midpoint between two

railroad rails, the removal of which make reestablishment of the right-of-way (ROW) boundary difficult and expensive.

4. Alleys, access roads, and private roads: These often appear on maps that are made from aerial photographs, but those that are not created by a recorded instrument, such as a subdivision or easement, often do not appear on parcel maps.

5. Subsurface and air rights: These sticks in the "bundle of rights" are sometimes sold separately. They may or may not be included on parcel maps. Cases of elevated freeways or viaducts that pass over surfaces that have other uses can be examined to determine whether such rights are included on the parcel map.

6. Condominiums and time-share units: Unlike two-dimensional parcel descriptions, these units often have height and time dimensions as well. These dimensions, that are critical to accurate parcel descriptions, are difficult to show on parcel maps. Areas of common ownership present similar difficulties for the parcel mapper.

7. Commercial, industrial, and institutional parcels: These parcels refer to the use of parcels, as opposed to parcels that are owned by individuals for purposes such as residential.

8. Publicly-owned lands: These parcels are sometimes not included in jurisdictions in which they do not generate property taxes. In other cases, assessors are required to assess and map them, even though taxes are not collected. For example, these parcels may be taxable if leased for certain purposes in some jurisdictions. Procedures to update the transfer of private-to-public and public-to-private transfers may not include map updates on a regular basis.

9. Ambulatory (movable) boundaries: Some parcel boundaries are determined by the position of natural features, typically water (e.g., rivers, streams, lakes). These boundaries are often determined in a manner and timeliness different from boundaries established by human action.

Mapping of parcels will often reveal inconsistencies among the description of the same and related parcels that are displayed on the map. Efforts to resolve these inconsistencies when constructing the map can result in a long, expensive process. A reasonable approach is to map the parcels, relying on those descriptions contained in the attribute files (such as deeds, mortgages, and tax descriptions), which are, in the judgement of the mapmaker, the best representation of the parcel boundary. Then a carefully designed procedure is followed to refine the map over time. This refinement may, in some cases, require the use of land surveys, legal agreements, and court proceedings. The final product, no matter what the process, is a representation of the parcels whose usefulness depends upon the quality of the mapmaker's judgement and that of the underlying descriptions.

The development of parcel maps involves a series of integrated operations that involve compiling land parcel information and preparation of a graphical representation of this information. Ideally, the geodetic framework and base map will be in place before development or revision of the parcel map layer. Chapter 19 provides guidance as to how to proceed when these ideal conditions cannot be met.

DESIGN FACTORS FOR A PARCEL MAPPING PROGRAM

The following is a checklist of factors that should be considered when designing a parcel mapping program. Discussion and agreement by as many system users as can be identified, hopefully by consensus, will help avert problems later.

1. Reach agreement on scale, format, accuracy, and content, in addition to parcel boundaries, parcel definition, timeliness, and specific features that are not to be included.

2. The expressed and implied needs of each office, agency, organization, and individual who will use the parcel map should be defined in terms of item 1. above.

3. Establish processes with information providers for the specific records and their attributes that will contribute to the parcel map, with particular attention to the definition of the quality of each record.

4. Determine which office or offices has the responsibility for design decisions and arrangements for execution of the parcel mapping plan.

5. Determine whether the parcel map will be built on a day-forward basis or whether maps will be available for all parcels on a specified target date.

6. Determine how the parcel map is related to the base map for the same area and the set of land records which it serves to integrate.

7. Determine how gaps and overlaps among the parcels will be resolved if they appear on the parcel map.

8. Determine how the final product will be represented and characterized for external and public users.

USES AND USERS

Parcel maps information is linked closely to the functions of local government since so many local government functions are related to parcels and their attributes. The primary uses of parcel maps among local government agencies are:

- property assessment
- planning and engineering activities
- management of title records
- management of public utility and service systems.

In addition, parcel maps are used by both public and private people in ways not intended by those who participate in their construction. This situation requires parcel mapmakers to anticipate as many uses as possible and to adopt practices that reflect appropriate diligence in map construction and maintenance, and the provision of as much data as possible about the attributes of parcel map data used.

SCALE

An appropriate scale for the paper product that represents parcels is the smallest scale that legibly shows all the information that is appropriate for that product. Different products may be prepared for different purposes. Parcel size and density of descriptive information that are to be included are the most important factors in selecting an appropriate map scale in this way. Since use and density of information usually vary, even within a jurisdiction, it is not uncommon for several map scales to be used. Parcel map scales typically range from 1"=50' (1:600) to 1"=800' (1:9,600). (See Table 13-1.) Comparable metric scales can also be used. Larger scales may be used in urban areas with high parcel density, with smaller scales used in rural and lesser developed areas with larger average parcel size.

CONTENT

Parcel maps generally include some or all of the items listed in Table 13-2. Due to the variation in scale and intended use, parcel maps may not contain information on all items or may contain incomplete information on some items. For example, parcel dimensions may not be shown because such information would crowd information on the map. Sometimes only street frontage dimensions are shown, since this item is often used as one of the factors in appraising value. In blocks where all the lots are of the same size, the dimensions may be shown only once. Other shorthand techniques may be used so that determination of parcel numbers and other information requires users have familiarity with the coding schema used. In some circumstances, specific information is not included because the data from which it is obtained are suspect.

Table 13-1: Typical parcel map scales

The following are commonly used mapping scales:

- o Urban areas: 1" = 50' (1:600) and 1" = 100' (1:1,200)
- o Suburban areas: 1" = 200' (1:2,400)
- o Rural areas: 1" = 400' (1:4,800) and 1" = 800' (1:9,600)

Taken from *Standard on Cadastral Maps and Parcel Identifiers*, IAAO, 1988, p. 7.

Automation of parcel maps often requires a change in procedures as to map content. For instance, in an automated system, dimensions of each parcel must be maintained in the data file, including provisions for dimension annotation on each parcel.

Table 13-2 also lists supplemental map information. This information may be on the parcel map, or it may be maintained separately. For instance, several of the items are often maintained on the Base Map that was discussed in Chapter 12.

MAP SHEET SIZE AND LAYOUT

Flexibility in scale and size of output information is one of the advantages of automated map data storage and manipulation. However, it is still a good idea to reach agreement on the common representations of parcel maps, including map sheet size, map name and numbering schemes, and similar attributes.

Multisheet map series typically use a grid of some sort to divide a large area into separate areas represented by separate paper products or map sheets. PLSS sections, quarter sections, or other comparable areas are often used. Provisions must still be made for odd sized areas along the west and north edges of PLSS townships for government lots and for land grants. The U.S. Geological Survey uses regular increments of latitude and

Table 13-2: Contents of the parcel map

Basic Information. Cadastral maps should contain the following:

- o Boundaries of all parcels
- o Parcel dimensions or areas
- o Block and lot numbers and, if scale permits, names and boundaries of subdivisions and plats
- o Boundaries of geographic subdivisions, for example, section, township, and range; government lot boundaries and numbers; land districts, land lots, and numbers
- o Location and names of streets, highways, alleys, railroads, rivers, lakes, etc.
- o Parcel identifiers
- o Other basic map information including a map number, title block, revision block, legend, map key, north arrow, and keys to adjoining maps.

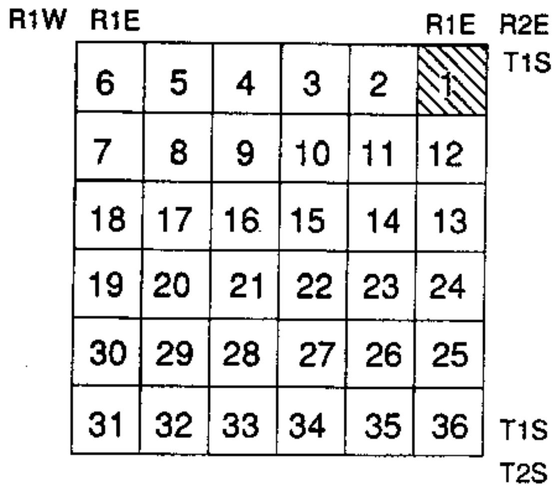
Supplemental Information. Supplemental parcel information should be recorded on overlays or a computerized data base. This allows access to as much or as little data as required without changing the original maps. It also facilitates use of the map data by other users.

Commonly collected supplemental information includes the following:

- o Right-of-way and easement boundaries
- o Names and addresses of parcel owners
- o Assessed values
- o Locations of improvements
- o Street numbers
- o Monumentation network coordinate listing
- o Zoning information
- o Special districts (e.g., voting)
- o Sewer and water lines
- o Waterways and county drains
- o Topological and topographical information
- o Soil types
- o Sales data
- o Deed and survey reference information.

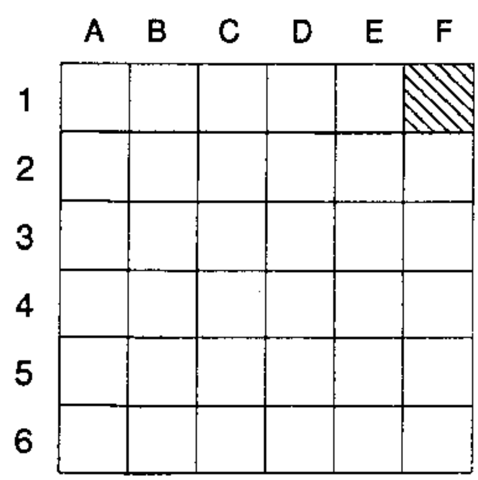
Taken from *Standard on Cadastral Maps and Parcel Identifiers*, IAAO, 1988, p. 7.

longitude for map sheet boundaries. State Plane Coordinate System, arbitrary, or even irregular grids can be used. Whatever system is chosen, it should conform to a uniform standard map sheet style, an easy reference system for identifying individual map sheets, and be suitable for use with other map products in the jurisdiction, such as the base map. Figure 13-1 (a-d) contains several map identification schemes.



Map Sheet: 01-1-1
Township: 1 South
Range: 1 East
Section: 1

Figure 13-1a: PLSS Township, Range, and Section Map Designation



Map Sheet: F1

Figure 13-1b: Arbitrary Coordinate Map Designation for PLSS maps

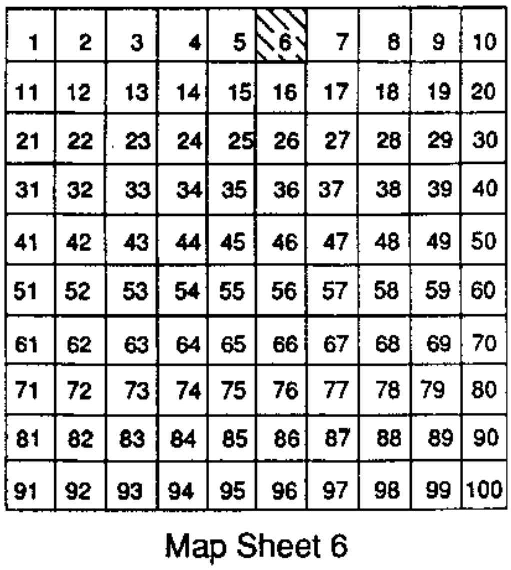


Figure 13-1c: Numbered Grid Map Designation

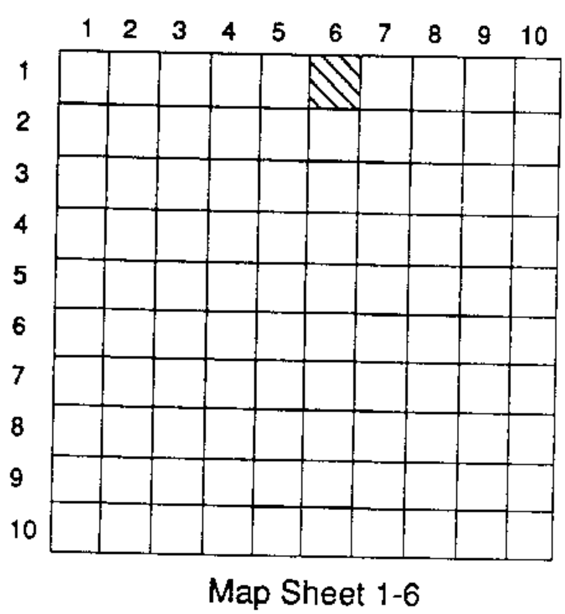


Figure 13-1d: Arbitrary Coordinate Map Designation

MAP COMPILATION

Five major tasks need to be considered when actually developing a parcel map system. These tasks include:

1. Assembling and weighting the source data
2. Constructing a framework for the parcel maps
3. Compiling the boundaries of parcels
4. Adding notation as needed
5. Maintenance.

ASSEMBLING AND WEIGHTING SOURCE DATA

The first task in the creation of a parcel map is to assemble relevant records from appropriate sources. These sources include:

1. Title records
2. Assessment records
3. Infrastructure records (highways, utilities, transmission lines, etc.)
4. Land use and zoning regulation records
5. Resource and environmental records
6. Court records
7. Survey records (plats, plans, and surveyor notes).

These records may include graphics (maps and sketches) as well as attribute data from nongraphic record files. (See Chapter 9.)

The location of property boundaries requires consideration of boundary evidence in two forms: documents and observations of the land. This written and physical evidence must be gathered, evaluated, and arranged in order to make a judgement of the status of the boundary. The judgment must be consistent with rules of law and practice. Application of these rules to evidence in a specific situation is not a mathematically precise activity.

Each significant land transaction between parties is an opportunity to observe, measure, mark, and describe the extent of rights in land. The resulting representation or description is specific to the transaction and can appear to be independent of earlier delineations. However, it must be properly related to previous descriptions which purportedly apply to the same property but which may or may not be the same in form or detail. The physical and documentary evidence must be evaluated, and priorities assigned to this evidence before a conclusion is made about the extent of property rights. The most recent description, or the one with the most precisely measured distance, may not properly represent the boundaries because it is the result of an incorrect or inappropriate conclusion about the evidence. Correct conclusions, measurements, demarcation, and description are the result of a proper application of the rules of law to the set of boundary records and observations.

The order of importance of boundary evidence, written and physical, is as follows:

a. *Right of Possession.* This is a right based on long possession irrespective of any intentions and actions expressed in writings. In circumstances defined by law, the extent of rights in land is established by long use. Descriptions and markers set according to these descriptions yield to considerations of long use, regardless of other considerations.

b. *Senior right.* This exists when current or recent boundary evidence for adjoining properties reveals an overlap, and the properties share a common history in the sense that they were created from the same larger property. For example, a grant of the southern half of a property establishes a senior right in the grantee who receives the southern half. This right prevails even if a mistake is made in delineating and demarcating the new parcel at the time of the grant or in subsequent surveys and descriptions. The points here are that (1) there may be no uncertainty when the law is applied to evidence of a boundary established at the time of the grant and (2) the overlap may be the result of an easily identified, incorrect conclusion whose effect has been perpetuated in a series of subsequent descriptions. Thus, the appearance of an overlap in the representation of independently described properties is not necessarily a legal problem.

> An overlap suggests, but does not establish, a senior right. Sometimes, reference to an adjoining property is suggestive of a senior right. However, because adjoining properties can be described independently in subsequent transactions, it is not uncommon to find reference to adjoining properties inserted in descriptions subsequent to property creation. These conditions highlight the rule that determination of the status of boundary requires an examination of the title and boundary history.

c. *Conflicting Elements*. The material above indicates that the intention of the parties who create a property are disclosed by documents prepared and actions taken at the time the property is first established. Subsequent observations and descriptions (i.e., surveys) are efforts to redetermine and reestablish the intentions and actions of the original parties. The documents and actions are evidence of these intentions and actions. Their appropriateness and weight is determined according to the rules of law.

A search of the title and boundary documents and an examination of the property can reveal an array of measurements, names, objects, land features, locations, addresses, and other items used to distinguish and demarcate one property from another. These elements may or may not represent the same location on the ground. To complicate the matter further, a single description in a transfer document may contain several elements which, when considered in the field, may or may not be in conflict. A single description may refer to an adjoining property, a natural monument, an artificial monument, a distance, an area, etc. For example, a description that reads "...300 feet to an iron pin at the road..." contains at least three points that may or may not be at the same place on the ground --- the terminus of the 300 feet, the iron pin, and the road. Whether these elements are in conflict is not ascertainable from the documents, but only from observation of the land. Therefore, it is premature to declare that a conflict exists before a full investigation of both the documents and the land.

A general priority among elements used to distinguish, delineate, and demarcate property can be described based on law and practice. The order is not absolute. It varies according to the law and practice in a particular jurisdiction. The date of the document and action is important. It applies where the parties reduce their intentions to documents, actions, and descriptions. The general priority is as follows:

(a) Monuments placed and referred to in the transaction document that creates the property and expressing the intention of the parties. The transaction document that creates the parcel may refer to monuments explicitly or implicitly as in the case of references to the "northwest quarter of section 10..." or to a subdivision plat which refers to monuments. Subsequent monuments must be defendable as a representation of the original intent and monumentation. Generally, natural monuments, such as rivers and geological features, prevail over artificial monuments such as pins set in the ground. Natural and artificial monuments generally prevail over what are called records monuments, which are references to such features as roads, mentioned in connection with artificial monuments in the example above.

(b) Distance

(c) Direction

(d) Area

(e) Coordinates.

It must be emphasized that this ranking is not absolute. Even in a state where an examination of statutes and cases reveals that this priority is appropriate, it is likely that the facts in a specific case may result in a variation. The facts and testimony of the observer give a weight to the evidence, which can, in some circumstances, alter the general priority. A well trained surveyor should be consulted to help resolve inconsistencies and conflicts.

The boundaries of parcels are established by documents and actions taken at the time a parcel is created and by subsequent effort to sustain the intentions and actions taken at that time. Subsequent activity is measurable against evidence which can be shown to be more consistent with the original efforts. Therefore, it is not proper to assume that a recent description with measurements by the most modern and precise instruments determines the boundary. The lesson here is that a parcel mapmaker must indicate what data are used to make the map. These data can range from a representation of the most recent description of a single parcel, to a depiction of the results of a complete title and boundary examination and judgment for all parcels in a jurisdiction, with every combination between these extremes. Full disclosure of the nature of material that contributes to the parcel map is essential.

CONSTRUCTING THE FRAMEWORK

As noted throughout this Guidebook, the geodetic reference system is the basic framework or layer on which all of the MPLIS rests. (See Figure 11-1). In addition, the base map, tied to the geodetic reference system, provides further orientation for parcel map information. Building on these two basic layers, parcel maps are compiled and maintained.

In PLSS states, section corners and quarter corners may be sufficient to establish a framework for the parcel map. This is true if corner locations are known to an accuracy consistent with the required needs for information derived from products based on those locations, such as the parcel map. The spatial relationship between each boundary and the monuments to which it is tied must be known. However, the spatial relationships among monuments and therefore among monuments, objects, and boundaries, are frequently unknown. Therefore, the distinction between local survey control, such as a well maintained PLSS, and the geodetic reference framework becomes important.

It is important to remember that parcel boundaries generally cannot be directly observed on the ground or on aerial photographs except where conspicuous objects or activity demarcate the boundary. To compile a parcel map, it is necessary to establish a link between the parcel map framework, such as the local reference network, and the geodetic reference framework, to ensure that relationships between parcels and geographic features that can be observed in the field, are accurately reflected on the map.

Unfortunately, it remains true that in many PLSS states, existing parcel maps were created with boundary data compiled under the assumption that the reference framework consists of perfectly square PLSS sections. Since sections are usually NOT square, such an assumption about the overall geometry of parcels in an area creates problems when monumented positions based on that assumption are used to relate locations of objects and boundaries found on aerial photographs and other geographical representations.

Further details on how to build and use the framework needed for a parcel map program can be found in Chapter 19.

COMPILING PARCEL BOUNDARIES: GAPS, OVERLAPS, AND COMPLETENESS

Once relations between locations that constitute the framework are determined, the process of placing parcels within the framework begins. This process depends upon a prioritization of the parcel records and data as suggested above.

Standards and procedures for compilation and maintenance of maps must be documented and consistently followed in order to reduce liability for their use. Use of such standards is particularly important as an MPLIS is automated, whether or not the compilation is handled by a contractor outside the government agency itself (Epstein and Roitman 1987).

While all aspects of parcel mapping are important, particular attention should be focused on ensuring that all parcels are accounted for. Usually, the best available tool for such a check is the current assessment record. However, many jurisdictions do not include tax exempt parcels in their assessment files. Also, there are examples where as many as 20 percent of parcels in a jurisdiction are not in the current assessment record. A variety of procedures can be used for resolving such errors of omission, including field surveys. (Chapter 19 contains additional details on this process.)

ADDING ANNOTATIONS

Annotation is often one of the most time-consuming tasks in constructing parcel maps. Cartographic skills are required to place dimensions, parcel identifiers, subdivision names or references, block numbers, and other information on the map so it can be read and interpreted easily. Consistent lettering styles for each class of information contributes to legibility, as do general rules to govern the placement, angle, and orientation of text. In a computer mapping environment, the annotation rules are important in realizing the potential for flexible display of the data. Figure 13-2 shows the variety of information and the potential density of annotation. Placement of annotation on a separate layer increases the flexibility of mapping. However, caution in using this approach is necessary in automated mapping, especially when map output is often produced in a variety of scales which affects the density and placement of annotation. Good annotation is also crucial for the reduction of liability for use of the map products.

MAINTENANCE OF THE PARCEL MAP

Maintenance of the accuracy and timeliness of the parcel map is crucial if it is to serve its role as the basis for integrating a variety of parcel-related records and information. This point cannot be overemphasized. Parcel maps already exist in many jurisdictions. Development of a parcel map program does not automatically produce an MPLIS. The parcel map remains an historical document when it is produced if no provision is made for maintenance. The parcel map becomes part of the process labeled an MPLIS when it remains timely and accurate and the basis for

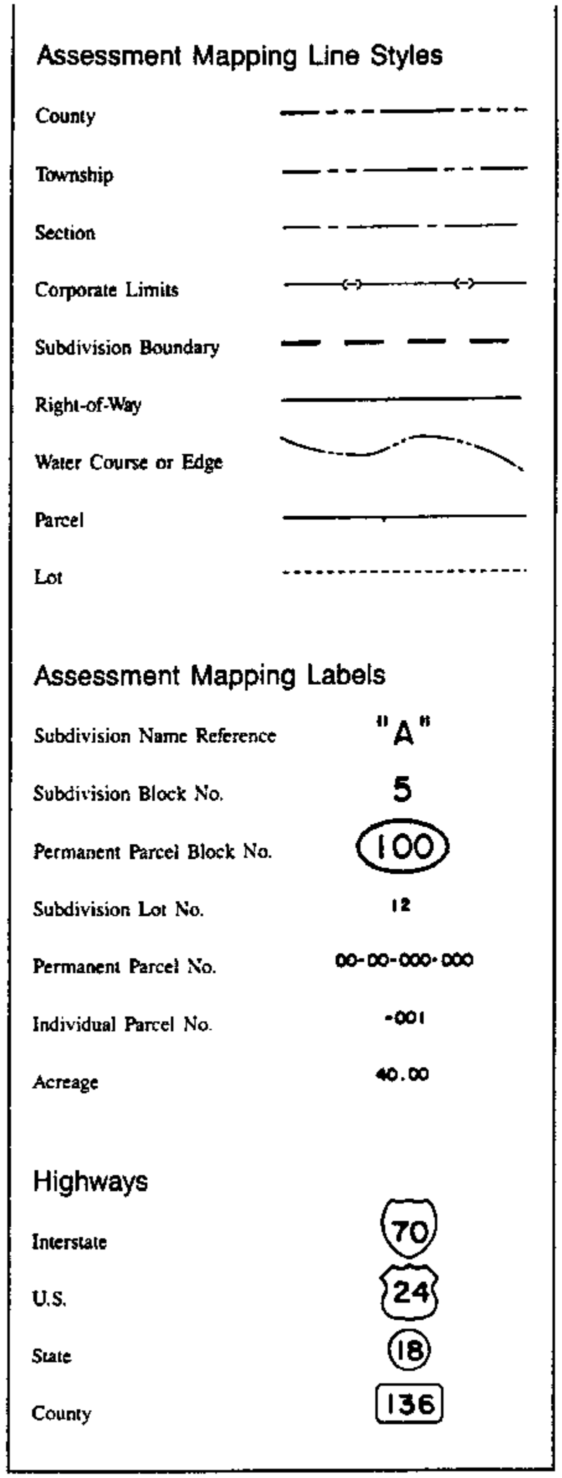


Figure 13-2: Typical Map Symbols (IAAO, 1988, p.8)

unique parcel identifiers that are attached to all parcel-related documents and for the general process of indexing parcel-related data and information.

The National Research Council (NRC) recommends that "the updating of [parcel maps] be scheduled so as to assure that they will reliably show any new or changed land parcels that have been in existence for two weeks or more. Where overlays are used by the recorder of deeds to display the parcel numbers used for indexing land-title records, this updating should occur within one week" (NRC 1983, p. 56). Achievement of goals such as this requires mechanisms exist for the unfettered flow of data between data gatherers and mapmakers.

Those agencies whose mandated activities rely on timely, accurate, and complete parcel boundary information are the logical ones to initiate and maintain the parcel map. Individual transactions that affect one or a few parcel boundaries, and result in boundary descriptions, are handled by subdivision review, planning, engineering, surveying, probate court, clerk, highway, register of deeds, building code inspection, and other offices. The assessment office is regularly concerned with all parcels in a jurisdiction. The important point is to assure that timely, complete information of known accuracy flows to the parcel mapmaker.

SUMMARY

Development of parcel maps is a crucial step in the development of an MPLIS. The parcel is a concept associated with rights and the relations between people in regard to land and its product. These relations are complex and basic in a community. Thus, a parcel is a complex concept and entity. Parcel maps found in local government offices reflect this complexity. The parcel map is a spatial representation of interests in land that were described in Chapter 4.

Parcel maps build on the base map layer, using a geographic framework to relate the locations of parcels within the parcel layer and to other MPLIS layers. A variety of records that delineate parcel boundaries are used to fit parcels together in a geographic representation. In order to create and maintain a parcel map of known and described quality, it is necessary to establish and supervise a process that ensures the unfettered flow of these records and their use according to appropriate standards.

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14 GETTING STARTED: HOW TO ORGANIZE YOUR IMPROVEMENT EFFORTS

Stephen J. Ventura

GIS-RELATED TECHNOLOGY IN LAND RECORDS MODERNIZATION

Hardware and software for automated land information systems (LIS) have become affordable and accessible at every level of government. Computers now offer data storage and instruction processing capacities rivaling computers costing many times as much a decade ago. Commercial software for both geoprocessing and database management has also become available, affordable, and understandable.

The commercialization of technology-based solutions for land records has set in motion a process that will have far-reaching effects on decision making in local government. Many departments and agencies are interested in implementing land information systems. It has been suggested that most decisions made by local government require some kind of information related to spatial reference. Many offices of planning, transportation, public works, emergency services, assessment, land conservation, and real property listing clearly can benefit from automated, integrated land records systems. Many other county and municipal departments and private companies such as utilities and real estate interests that use maps or other spatial data can benefit as well. Land records reform through automation has become a major goal of local governments across the United States.

But an LIS cannot be implemented simply by buying hardware and software. These and other components of a system must all be carefully matched to an organization's needs and characteristics.

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When computer-based technologies have been determined to be appropriate for a jurisdiction's land records modernization process, it is important to begin an implementation carefully. Many of the initial decisions made before and during implementation can have profound effects on the long-term efficiency and effectiveness of a system. These initial decisions include how people learn about the system, how needs assessment, requirements analysis, and system design are conducted, and who is involved in these processes.

Other chapters of this GUIDEBOOK offer information on specific problems. Technical issues, such as user needs assessment and functional requirements analysis, discussed in Chapter 16, should help an organization determine the scope of a project, which departments and applications to include in a system, what kinds of data to automate, and which preliminary decisions about system design must be made to write effective requests-for-proposal (RFPs) for hardware and software. Institutional issues, such as funding and benefit/cost analysis (Chapter 15), organizational and administrative changes (Chapter 8), and institutional arrangements and cooperative agreements (Chapter 17) need to be considered during implementation as well. Chapters on automation (Chapters 21-24) detail hardware, software, systems design, and particularly data-related issues such as sources, conversion strategies, integrity, compatibility, and management. Addressing technical and institutional issues provides a sound foundation for the negotiation, persuasion, compromise, insight, and risk-taking necessary to implement an LIS.

The purpose of this chapter is to instruct the reader on the very first steps in implementing an automated LIS -- selling the vision, laying the groundwork for understanding technical and institutional issues, assessing methods for learning about LIS, and determining the initial scope of a project. This latter decision, early in the implementation process, can be critical. An organization must find a balance between including enough participants to achieve the benefits of an MPLIS and keeping the project small enough to be manageable and affordable.

Much of this chapter is based on the assumption that the group or individual responsible for local land records modernization will "cast its net" broadly to involve many departments and agencies in a land information system that provides benefits for a broad group of public and private users. Whereas it is possible to automate the function of a single office or limited group of offices, positive benefit/cost ratios are most often found when many users can share data, technical expertise, equipment, and costs. Although it might require more effort to start a system that meets the needs of many users, long-term benefits are more likely to result, and the benefits are likely to be larger.

Including others requires commitment to and agreement on data handling. One model for an MPLIS (Chapter 7, Figure 7.5) includes data custodians -- agencies or offices with statutory responsibility to maintain land records who have agreed to maintain automated land information in a form and format such that it can be shared with other groups as needed. To be successful, this requires institutional agreements on issues such as a common geodetic reference framework, data exchange, and quality standards. As a consequence, the initial contact with and education of potential participants is an important part of "getting started."

OVERVIEW OF LIS IMPLEMENTATION

LIS implementation typically follows a sequence of about six distinct steps or stages. This chapter provides detailed information on the first step -- the introduction of the technology. Other steps are discussed in depth elsewhere in the GUIDEBOOK, but this section provides a brief overview of those other steps to help the reader begin to construct a picture of how to organize implementation efforts.

An organization must first be introduced to new ideas and methods -- the technology introduction -- both to convince people in an organization to give the new methods a chance and to explain the implementation process, particularly the next step, which requires their direct participation. This next step, commonly called a "user needs assessment," examines current and prospective land records activities, considering people and how they use the data.

After the "people" side of record keeping and use has been examined, the next step, "system requirements analysis," is to determine what will be needed to automate the procedures and analyses. This must include the hardware, software, and personnel resources needed to automate, maintain, update, and access the data in an automated, integrated system.

A system design can be developed after requirements in terms of information, software, hardware, institutional arrangements, and other system components are determined. This should be accompanied by an implementation plan, which specifies how to get from current methods to the envisioned system. When the system is finally ready to run, pilot projects can be undertaken to gain experience and support for the new system before major changes are made in operating procedures.

TECHNOLOGY INTRODUCTION

A technology introduction includes exposure to GIS concepts, hardware, and software prior to adoption by an organization. Vendor seminars, workshops, conferences, booklets, and demonstrations are all suggested means for this preliminary preparation and education. In many cases, technology introduction is also part of the process of convincing decision-makers to invest in the technology. It is also helpful to present the process and expectations of the needs assessment and requirements analysis to potential users, so they are prepared to explain their use of spatial information in their day-to-day operations.

USER NEEDS ASSESSMENT

The purpose of a needs assessment is primarily to identify potential LIS users, determine what users do, how they do it, with what data and analytic techniques, and how they might be able to take advantage of LIS technology. The needs assessment typically covers:

- who uses an organization's land records?

- what kinds and forms of data are managed?

- how are data used: what analyses are done; what decisions are made; what information products are generated?

- how often are the various types of records accessed and updated?

- who has the responsibility for data maintenance?

- what improvements might be possible through automation: what can users do more effectively or efficiently; what is possible that wasn't possible with manual methods?

The needs assessment almost always consists of surveys and interviews with potential users of LIS, and might be supplemented by examining existing studies, documents, and legislation. Needs assessment can identify the goals and objectives of the LIS, the bounds of the project, and the connection of the LIS within and beyond an agency, as well as additional detail about specific applications.

The expectations from needs assessment vary widely. Results of an assessment can range from being the entire basis for system design to being completely data oriented. In addition to exploring the data needs and types of applications of spatial data users, areas of inquiry include frequency of transactions, the rates of information flow, the accuracy and currency required for various uses of data, the frequency and types of requests, and the required speed of delivery. In many cases, a user needs analysis can provide an assessment of the level of knowledge of users, as well as some indication of how much time and effort must be expended on training, application software, and user interfaces.

A user needs assessment can play a fundamental role in facilitating system design. This is especially helpful if an organization starts without strong preconceived notions of which particular LIS software and system design are most appropriate. Software vendors who also implement systems might be interested in adapting their products and services to users' needs, and so concentrate primarily on tasks and data and how their proposed solution can manage them, without dealing with organizational and institutional aspects of design.

Some user needs analyses have been criticized for missing opportunities that LIS offers. Users unfamiliar with the capabilities of the technology might not be able to adequately verbalize their spatial data problems and might not be able to conceptualize what can be done with LIS. In the user needs process, users must have a sufficiently adequate understanding of LIS to "dream big" -- to be able to envision what they might do with an automated approach, things that were too costly or complicated to do with manual methods. In most cases, LIS can do much more than simply automate existing procedures.

SYSTEM REQUIREMENTS ANALYSIS

This analysis is the process whereby user needs are translated into the technical requirements of a system, including hardware and software configurations, data sources, and data management procedures, data accuracy requirements, and the kind of information products that need to come from the system. A requirements analysis determines what will be needed in terms of:

- software functionality;
- computer hardware and peripherals, including input and output devices;
- data storage volume and data access speed requirements;
- data standards, including data quality and data exchange;
- technical expertise, staffing, training;
- system startup and maintenance costs.

This analysis can be done in combination with either user needs assessment or systems design in step-by-step implementation procedures. If the objective of this process is to develop an RFP, requirements analysis should include specifications for needed LIS software functions as well as hardware requirements. A requirements analysis might include a technology assessment to make sure that expectations of the system are reasonable. Requirements analysis might consider additional factors such as staffing, physical workspace needs, support personnel (especially programming support), security considerations (for data and equipment), and cost accounting and efficiency measures.

Of primary concern in requirements analysis is determining software functionality -- its capability and capacity for LIS applications. The elements of functionality -- for example, data automation, management, analysis, and display functions that LIS software is capable of -- can be used to determine what will be required in an RFP, given present and future applications. Hardware represents a substantial part of an initial investment in LIS, but the considerations are straightforward and secondary in importance. Basic advice is to "buy the fastest machine with the most memory that is within your budget." In general, software should be selected first (or simultaneously); the "platform" must support the software that is chosen. Some additional requirements concerning data models, system design, and integration of new technologies into an organization should be considered before making a commitment to a particular hardware and software solution. It is appropriate to develop RFPs only after an organization has a strategy for evaluating software and hardware needs (benchmarking) and for effectively organizing and using these new tools.

The Federal Interagency Coordinating Committee on Digital Cartography (FICCDC 1988) provided a good list of generic GIS functionalities that can be used to guide the selection of software requirements for specific applications. Table 14-1 is a list of generic GIS functionalities, modified and enhanced from the FICCDC list. The FICCDC report also includes a list of hardware components and some evaluation criteria.

SYSTEM DESIGN

System design efforts range from models for the institutional arrangements needed for a multipurpose system to data models to the configurations of hardware and software. A leading vendor suggests that a conceptual design includes application module designs, a data base model, hardware and software specifications, and an administrative framework. The "data model" can consist of many components including data flows, data structure and format, entity relationships, query processing, user interface methods, and data indexing and archiving procedures.

Many choices must be made in designing an LIS, often involving tradeoffs. For example, a highly customized system might be easy to operate, but have limited flexibility, or a detailed database might have all the information "on-line" for any possible query, but might be slow to respond because of large data volumes.

An organization is best served if choices in system design arise from the results of user needs assessment and requirements analysis. The system can also build on currently successful applications, rather than assuming they must be replaced. Evidence suggests, however, that software selection and/or data sources are too often the most important factors in system design. This is often the result, for example, of consultants being familiar with only one software package and invariably recommending that package as the solution. Knowledge about available options is the best way for an organization to avoid getting boxed into a particular solution that might not be optimal.

IMPLEMENTATION PLAN

An implementation plan is generally an incremental work plan. These plans might detail who is responsible for which tasks, when they will be started and finished, and what resources (funds, data, and staff) will be needed. The plan can specify individual responsibilities in data management, data base and equipment maintenance, and vendor and agency liaison. The plan can also be simply for general work flow and staffing. In many implementation plans, preparation of staff in the use of new equipment and procedures is absent or not well developed; such activities should be included. Table 14-2 lists some activities typically included in the planning necessary to integrate new computer-based technologies into an organization.

PILOT PROJECTS

Pilot projects, demonstrations, and benchmark evaluations provide experience on a small scale before full commitment to new methods. Most LIS implementors indicate that projects in a limited geographic area or for a single application are essential for success. They introduce users to hardware and software, help identify problems or bugs in the system before full commitment, allow comparison of various solutions and approaches, and facilitate preparation of attractive hard-copy information products for decision-makers who must be convinced of the system's viability.

The pilot project also provides a way of testing new applications before an agency makes a full commitment to automated methods. The methods and procedures can be fine-tuned by skilled problem-solvers before everyone is expected to use them. Personnel can be gradually trained in more automated individual applications, easing the transition rather than radically changing all daily routines at one time.

INTRODUCING LIS TECHNOLOGY TO AN ORGANIZATION

The purpose of a technology introduction is two-fold. First, it exposes an organization to the new concepts and methods: what are the new techniques, equipment, and methods; how might they change operations; how will products or services change; and what are the potential costs, benefits, and other implications of the new technology? Second, it introduces prospective users to the implementation process: how will the organization make a transition to the new methods; why and how will they participate in the user needs assessment; and what is their likely role in the long-term use and maintenance of the system?

An LIS plan and its implementation are, in essence, a technology transfer process. Technology transfer cannot take place without someone taking a leadership role. That someone must be able to sell a vision of what LIS can accomplish in an organization, both to personnel who will ultimately use the system and to decision-makers who must commit funding for it. Change is resisted in many organizations; persuasive arguments about the benefits of a technology might be a necessary part of the implementation process. Without an effective introduction to benefits, costs, and consequences of a new approach, neither users nor decision makers are likely to embrace the ideas.

SELLING THE VISION

"Selling the vision" is best done by a champion (or champions) of the technology within an organization. The champion must be an effective spokesperson and organizer, able to see the bigger picture and to involve others. Hired consultants can be effective in persuading and educating, but initially there must be someone who has a vision of the organization, who is willing to promote the technology, to explain the concepts (or bring in experts who can), to make at least the initial choices about the scope of the project, to decide who to include in planning and design sessions, and generally to foster and facilitate change. This facilitator must put in place a mechanism to deal with difficult institutional issues such as long-term funding commitments, restructuring of an organization, new relations with other organizations, data security and access, etc. Without this facilitator, an LIS implementation might be impaired and the benefits limited.

To some extent, the champion must be a risk-taker. When technical shortcomings or institutional roadblocks impair a project, a champion might be exposed to unflattering professional scrutiny. When people's work activities are altered by LIS implementation or "skeletons in the closet" are revealed during the process, the champion might be personally impugned. Indeed, inspirational stories surround some of the early LIS implementors, such as

Eunice Ayers (Forsythe County, North Carolina), Murray Rhodes (Wyandotte County, Kansas), Dale Friedley (Florida), and Bob Cook (Cincinnati, Ohio), and how they overcame many odds.

The champion must have technical expertise, or must work with someone else who will be responsible for technical aspects of implementation. For example, in the early 1980s, Murray Rhodes worked closely with Ed Crane: Rhodes fought the political and economic battles, while Crane solved the difficult technical problems in Wyandotte County, Kansas. Having simply an "LIS implementor" might not be sufficient to provide the leadership needed to overcome the institutional and technical hurdles.

The champion should be able to transform technical jargon into decision makers' own frames of reference. The champion's approach during an introduction to LIS must emphasize the efficiency or effectiveness of new methods, rather than presenting information that might sound like abstract or arcane technical concepts. Once a commitment to implementation has been made, technical experts can introduce specific concepts and terms in a formal or informal training process.

The champion must ultimately be able to "let go" of the process after successful implementation. Given the goals of LIS capabilities distributed broadly through an organization and end-user involvement in system design, the technology should permeate the organization and users assume responsibilities. Ideally, the champion initiates the interest in the new ideas for an organization and then provides enough guidance and standards that the technology doesn't run out of control, a situation that could result in merely automating existing problems.

The best champion might well be one who is self-selected, the true believer willing to take on the inertia because the belief is so great. A designated champion seldom fills the role with the same degree of enthusiasm.

LAYING THE GROUNDWORK

Technology introduction has a direct impact on subsequent steps in an LIS implementation process. In addition to wanting to understand the technology in general, potential users want to know specific details about the implementation process and expectations of the needs assessment and requirements analysis. They want to know why the needs assessment interviewers are asking so many questions about how they do their job! To answer the assessment questions effectively, users need at least a basic understanding of spatial data and LIS so they can explain their use of spatially-related information, how data could be used in an automated form, and how work products (services, decisions, etc.) could benefit.

A successful LIS implementation requires interaction and feedback between the end users and the technical experts helping to design a system and build applications. Continual feedback throughout the entire implementation process is helpful. It provides immediate evaluation of the utility of the experts' efforts, and gives end users a voice in the process. It is appropriate to initiate this feedback upon first exposure -- during technology introduction. This can open communication channels and build confidence in the experts who are guiding the implementation.

LEARNING ABOUT LIS

Adoption of geographic information systems and related technologies has accelerated dramatically in the last few years. At the same time, there has been an explosion in information about LIS. This means there might be too much information available, too much to sort through to determine what is valid, unbiased, and applicable to particular local circumstances.

Finding objective and reliable advice can be one of the most challenging aspects of LIS implementation. Information that purports to explain LIS is available from a variety of sources. It isn't possible to say which might be misleading or biased, but one piece of advice is always valid: an organization buying into LIS must get more than one opinion and must refer to more than one source. It must be an informed consumer.

CONSULTANTS

Expertise for designing and implementing an LIS obviously can be obtained by hiring the right people, but finding the right consultant for a situation will require some effort. A few precautions are in order before an organization begins to search for that service.

Consultants might be vendor-allegiant or vendor-neutral. Vendor-allegiant consultants consistently recommend the software packages and/or computer hardware that they represent. If the hardware or software is not appropriate for a particular situation, the consultants might go to great lengths to try to adapt it anyway. Nonetheless, many vendor-allegiant consultants are reliable and can address specific problems and issues. On the other hand, vendor-neutral consultants generally concentrate on specific needs of a situation and try to find the best solution, though they too can be limited in experience or range of knowledge.

Consultants can have a wide range of LIS experience. LIS is considered to be a growth area and many people have only recently begun to work in this arena. Many companies that specialize in related fields such as surveying or photogrammetry now offer LIS services. Such companies might offer excellent help, but they might also be narrowly focused on particular aspects of a larger implementation process such as data automation. No formal certification of LIS consultants exists, but reputable vendors will respond to "requests for qualifications" -- descriptions of the kinds of projects they have been involved with and the training of their personnel. Prospective consultants should be able to provide names of former clients.

Consultants might try to simply "please the client." They might avoid controversial or expensive recommendations, even if evidence suggests that those might be good ways of accomplishing goals. Before working with a consultant, an organization should have clear ideas about its long-range goals. It must communicate these goals, then ask the consultant to work on more than one alternative for achieving these. This allows the client to evaluate trade-offs between various approaches.

Consultants might try to make themselves indispensable in the long-term functioning of an LIS. To avoid this, there must be a clearly detailed process for transferring knowledge about system design and operation to permanent personnel. Staff should also be trained in the development of new applications, so a client doesn't have to retain consultants every time a new need occurs.

An important consideration in selecting a consultant is finding someone who has a thorough understanding of GIS technology and either knows or has a well-defined process for learning the operations of an organization. Finding a consultant can be as easy as looking in a local community or as complicated as developing and circulating a formal RFP nationwide for consulting services. The advantage of finding a local consultant is the likelihood that the firm's personnel will already be familiar with the local situation. It is desirable to make sure that the local firm's personnel keep in touch with new trends in the technology; LIS is a complex and rapidly evolving field, and hardware and software in particular can become dated rapidly.

If there is no one locally available who is appropriate for the task, an office can turn to the many companies specializing in LIS implementation. Professional associations are a good place to find out about such companies. Several professional organizations (Table 14-3) are partially supported by the vendor community, including LIS consultants. These associations produce journals, newsletters, and pamphlets that contain descriptions of corporate sponsors including consultants, along with their advertisements. A number of newsletters and magazines about GIS also contain advertisements from and articles by consultants.

In most cases, consultants and vendors are willing to demonstrate their services or products without obligation. This can be done on site, at another implementation site, or at a trade show or conference. If an organization has sufficient confidence in its own knowledge of the technology, this is an excellent way to become familiar with the consultants' approaches and the ranges of their expertise. However, such a demonstration can also be a "hard sell," so one must be prepared to ask questions and visit more than one display or site. Demonstrations are generally focused on hardware and software, whereas a new system must also account for personnel, training, financing, institutional and inter-departmental arrangements, and so forth.

Site Visits

Most public employees are willing, if not eager, to show off innovations that have helped them do a better job. Visiting such sites removes the slant of consultants' interpretations. One can get more open answers about system implementation, operation, and cost. There are lessons to be learned from both successes and failures. The adjustments and adaptations to make commercial products work in a particular situation are important lessons. In addition to other local government systems, there are LIS facilities at utility companies, state agencies, and universities that can provide ideas and information.

The most useful information is likely to come from sites that are similar to one's own - in size, project scope, applications, budget, staff technical expertise, and so forth. This doesn't mean, however, to exclude all the "Cadillacs." For example, a rural county's budget or experience might not be similar to a large city's, but the latter operation might have many methods and procedures that could be cost-effective or efficient in the rural situation. Moreover, the steadily decreasing cost of computing might mean that some of those advanced features in equipment and software will be available in the near future on less expensive systems.

Books, Professional and Trade Journals, and Videos

The rapid diffusion of LIS technology has been accompanied by a phenomenal growth in published material. The first general textbook on geographic information systems was published in 1987. In 1991 there were over half a dozen to choose from and several others in the works (Table 14-4). The first video on land records modernization was produced at the University of Wisconsin-Madison in 1986. URISA, ACSM, AM/FM, and other professional associations have produced new videos, as have many vendors and consultants.

For the novice, the amount of written and video material available can be overwhelming. It can be difficult to ferret out what is important, relevant, or, even, true. Implementors of an LIS should ask counterparts and peers what has been useful to them.

Several professional journals and conference proceedings concentrate primarily on LIS and related technologies. Each of the professional societies listed in Table 14-3 publishes at least one journal and sponsors at least one annual conference with published proceedings. Each professional society has a slightly different focus. URISA, ACSM, and AM/FM are most likely to have articles of interest to local government, but all the others occasionally have applicable information. Other professional associations occasionally have journal articles or conference proceedings of interest.

Trade newsletters and magazines come and go too quickly to list them all. A recent report listed 92 newsletters and publications devoted to GIS and remote sensing. When an organization begins investigating LIS hardware and software, it will undoubtedly get on the mailing lists of many of these. Two in particular are worth noting: *GIS World* (bi-monthly; by subscription; see Table 14-4, the address for *The GIS Sourcebook*) is a good source of information about GIS activities of the federal government, states, larger cities, counties, and utilities, and of the nationwide vendors. *Government Technology* (monthly; free; 1831 V Street, Sacramento, CA 95818) often has good articles about implementation of LIS systems in a variety of public offices.

For those who need a quick introduction, videos present an easy, non-intimidating means to become familiar with LIS. Prospective users can absorb the information in comfortable surroundings without the accompanying high-pressure sales pitch. Although only a limited amount of material can be conveyed in a 20- or 30-minute video, it can be enough to draw people into the process so they want to find out more. URISA recently released a video about land information systems targeted at elected officials and upper-level management in local government. A video produced by the University of Wisconsin specifically addresses the concept of the MPLIS in local government. Software vendors are another source of videos, though they often carry a strong sales message.

Conferences, Seminars, and Workshops

Just as there is an explosion of written material on LIS, there is a corresponding explosion in meetings about it. Conferences provide opportunities to hear different viewpoints -- from those involved in day-to-day implementation and management, from vendors and consultants, and from academics studying the whole process. Seminars and workshops can provide an opportunity for in-depth information about particular aspects of LIS. Many newsletters have listings of upcoming meetings, conferences, and workshops.

Again, the wise consumer would learn something about the various meetings before committing time and money. It helps to know who is sponsoring the event; is it only one vendor? Is the main purpose to educate and disseminate information, or is it to make sales for the sponsors? What are the affiliations and reputations of the speakers? If it is a seminar or workshop, is there a "hands-on" component? This could be most informative. Learning, especially learning software, is much easier by doing.

STEPPING STONES FOR INTRODUCING LIS

Of course, there is no one right way to introduce innovation to an organization. Many different circumstances (organizational structure, financing, technical expertise, etc.) and presumptions about LIS (ranging from fear and rejection to blind, dogmatic faith) abound. One possible pathway to begin an LIS implementation involves five kinds of activities.

IDENTIFYING RESPONSIBLE PARTIES

A wide range of skills, both technical (data management, hardware and software, and training) and institutional (financing, political support, and intra- and inter-agency relations), is needed to lead system implementation. As a result, leadership might come from an individual or a small committee of those responsible for leading various efforts. Eventually, it might be desirable to have a much broader "steering committee" that represents interests of many users of a system. But in these early stages, effective leadership is generally provided by a small group responsible for learning and addressing a range of issues.

EDUCATING IMPLEMENTATION LEADERS

Implementation leaders don't have to know everything -- just enough about the aspects of LIS to effectively deal with others involved in the process. To convince decision-makers to support a new approach, implementation leaders must be able to convey efficiency and cost arguments. To work with consultants, they must be assertive, effective communicators and be able to detect misleading claims. To work directly with potential users, they must also have a good technical grasp. Implementation leaders might need intensive training best acquired at workshops and short courses. They could benefit from site visits and should become familiar with a variety of printed material.

CONVINCING DECISION MAKERS

Upper level management and elected officials need to know that changes are necessary. In most LIS implementations, up-front costs are large and paybacks are gradual. Unless decision makers give their long-term support, the system could be derailed before it is fully operational. Technology introduction for this group is oriented toward the costs and benefits of LIS. This group doesn't need technical details, but description of the tasks ahead should not be oversimplified. It is most important that what can be reasonably delivered is not oversold or over-promised. Videos might be an effective way to reach these people, along with personal visits and briefings. If used at all, written material and presentations should be short and concise.

CONDUCTING A PRELIMINARY CENSUS

A census should be made of prospective spatial data users. A preliminary questionnaire (see Appendix 1 for samples) can serve two purposes. One is to select initial project participants from the broader group of all users of spatial data in local agencies, locally active state and federal agencies, utilities, and companies. The second is to identify basic data resources and custodians. When questionnaires are tabulated, it might be helpful to hold a general public forum to explain the results and outline the project scope and goals.

INTRODUCING USERS TO THE TECHNOLOGY

When a commitment has been made, the training and education of potential users can begin. In-house demonstrations and seminars are the most effective way to reach a large audience. For example, a consultant could present a lecture for an hour or two, and then provide live demonstrations for smaller groups through the remainder of the time. Prospective users should get an introduction to the basic concepts of LIS, including data automation, management and analysis, and information products. Written material such as newsletters and memos can be used to explain the goals of the implementation process and how users will be involved in needs assessment. Users who will be most affected need to become prepared for a change. Some people should be warned that automation might profoundly change their responsibilities and day-to-day tasks. These should be regarded as positive changes, helping them do their job more efficiently and effectively. It is essential, however, that the tasks ahead are not oversimplified and that it is understood that the new methods will not solve all their problems.

SCOPE OF THE PROJECT

LIS implementation begins by decision makers making a commitment, system implementors learning the technology and the implementation process, and users understanding the concepts of LIS. But who are all these users and which decision makers must make a commitment? Which departments, individuals, and applications will be included in the initial detailed needs assessment? Which might be added sometime later? Which are probably not amenable to incorporation into an LIS? Before beginning the next steps in the implementation process -- user needs assessment and system requirements analysis -- it is necessary to make some decisions about the initial scope of the project.

The scope of the project should not be limited until a preliminary census of spatial data users has been conducted. There is a risk of losing contributing participants, data sources, or other resources if preconceived constraints or hasty benefit/cost analyses limit the scope. When agencies' interests, data, resources, etc., have been sketched out, the scope of a project can begin to take shape.

LIMITING OR EXPANDING AN LIS

The appropriate scope of an LIS implementation depends on the situation -- available funding, available expertise, status and interest of prospective participants, mandates governing their responsibilities, types of applications and data, personal or professional conflicts, existing agreements, and so forth. Many of these factors will become clearer during the needs assessment and requirements analysis, and as a result will be reflected in a system design or RFP. But, it is necessary to make some initial decisions about whom to include in the technology introduction and needs assessment processes. This amounts to making a number of trade-offs.

The benefits of an MPLIS will accrue more rapidly in systems that incorporate many applications and departments. Many users will be able to work from common databases, i.e., from the same set of facts and information. As a result, duplication of effort and redundant data sets can be eliminated and more accurate, complete, up-to-date information should be accessible from each custodian -- that is, the departments or agencies agreeing to maintain part of the system or its data.

These benefits will be countered by increased complexity of the project as more participants are added. It will be more difficult to set priorities. Every step will have a longer lead time and it will be more difficult to develop and adhere to timelines. More decision makers -- upper-level management and elected officials -- must be involved. The system and database design will be more complex, quite probably involving more formal methods such as on-line data dictionaries and structured systems analysis.

If the costs of a more inclusive system are shared equitably, everyone should benefit. Though there are likely to be larger start-up costs, these and maintenance costs will be spread among a larger group. Duplication and redundancy in data collection and management and in technical expertise should be reduced. Not every department will need several trained LIS experts. The entire array of hardware, software, and, in particular, peripherals that are only used occasionally won't have to be purchased by each participant. Widely used equipment such as terminals or workstations might be purchased at volume discounts. The net result can be substantial cost savings.

The equitable distribution of costs can be a difficult issue though, particularly when groups have very different data quality standards. If one group requires very accurate and/or very current (therefore expensive) data, there is the question of whether that group should bear the entire cost increment of the additional accuracy or if the cost should be spread among all users. If agreement can be reached on these tradeoffs, the benefits of an automated LIS will be spread over a larger group of participants. As spelled out in some detail in the next chapter, accounting for costs and benefits in an LIS is not always a simple task. In light of this uncertainty, an incremental implementation should provide a few immediate returns, which should engender sufficient support for the system to realize longer-term benefits.

In situations where there is little experience with GIS technology, it might be appropriate to start small, with only a few participating departments. The reasons are similar to those for doing pilot projects. On the technical side, it provides experience in the use of hardware and software and allows comparison of various approaches and solutions before too much is dependent on the system. On the institutional side, it provides cost/benefit information and products that are visible demonstrations of the system's benefits. This approach of building from limited participation will allow negotiation of cooperative agreements among departments or agencies, to grow as needed, rather than to force linkages in response to overt pressure or crises.

In a general sense, systems can be designed with the capacity to expand and incorporate new users. As the institutional and financial details are worked out, new users can be accommodated. Some efforts, however, might have to be redone at a later date, when greater accuracy or capacity is needed. For example, digitizing existing tax parcel maps creates a land ownership "layer" quite adequate for many applications such as resource management and planning. More accurate "coordinate geometry"-based mapping is needed to support tax assessment or conveyancing, but this might not happen for some time. These accuracy/speed/cost/scope-of-applications trade-offs are especially critical in the creation of base maps and geodetic reference frameworks.

IDENTIFYING PARTICIPANTS

Almost everything done in local government can be tied to a spatial location in some way. Even legal and judicial systems or social service departments must maintain addresses of clients and facilities, and might want to plot incidents such as crime or accident locations to relate them to other spatial variables. To keep a land information plan manageable, however, it is necessary to identify those departments central to land records modernization. These are primarily those departments that record or produce basic spatial data or are large-volume users. After the system develops, other users can be added. When the system is technically mature, additional users will add detail and richness to the system, and enhance the utility for all.

Several types of data, such as land-ownership-related data, are clearly important to an LIS. In most cases, the departments or agencies likely to be custodians of these data are obvious. It is important to include these entities in the initial decisions about system scope, design, and implementation, though they need not all be full users of the system from the start.

Table 14-5 is a generic list of many county, municipal, and town functions or offices that might be interested in participating in an LIS. It also includes state, federal, and private agencies that operate at the local level. A two-tier user needs assessment might be useful for screening the interest and commitment of these groups. A questionnaire (Appendix 1) can be used to find out who has what data and whether they are interested in working together on a multipurpose system. Such a questionnaire, with a simple memo explaining its purpose, can be distributed broadly within and beyond an organization with little effort. Response might be better if the questionnaire goes out under the signature of a prominent official such as a mayor or county executive.

On the basis of responses to the questionnaire, groups that have important data and/or have applications that readily fit within the scope of the system can be included in a more detailed needs assessment and system requirements analysis as outlined in the other chapters.

ENSURING FULL PARTICIPATION

Responses to the initial questionnaire might show that some departments or individuals who control important data sets are reluctant to participate in LIS implementation. Even some of these who appear to be responsible for data sets critical to the LIS might not be willing to participate in the process. This can impair the effective design and functioning of a system. Fortunately, there is a variety of ways to overcome these barriers.

Education is a valuable tool for overcoming the fear of change. Some people dislike or distrust computers in general; some might fear that their positions will be eliminated or that their authority will be reduced. Such fears generally arise from misunderstanding. If people are willing to listen with an open mind, they can generally be persuaded to at least give new ideas a try. These people might need personal attention in technology introduction, specifically using examples from their type of operation and addressing their concerns directly.

Sometimes individuals within a department are particularly willing to make a commitment to the new approach. Those contacts should be carefully nurtured. It is, after all, people who make these systems work. If a few people take the risk and begin using new methods, others will look over their shoulders to see if and how things work. In this way, more participants might be drawn into the process as they see for themselves that new methods are in some ways an improvement. The more people who become interested in the process, the more supporters the LIS will have.

Individuals or departments might also be reluctant to change because of "institutional inertia." They might already have considerable investment in existing methods such as manual cartography or drafting. They might feel that they are adequately fulfilling the requirements of their mandates. They might have "skeletons in their closets" -- inadequate or undocumented record keeping that they don't wish to expose to the scrutiny of a needs assessment.

It is possible to overcome institutional inertia through education, convincing individuals or departments to look at the overall good of an entire organization rather than more narrowly at their own responsibilities and budgets. Individuals or departments must be convinced that they won't be punished for past inadequacies, and that the LIS implementation is an opportunity to make reforms.

It might be necessary, in some cases, to promote change from higher levels in an organization with recalcitrant departments or individuals. This means first convincing upper-level management or elected officials of the importance of the new approach. They in turn can use their influence and directives. It is, however, the educational aspect that will provide the most lasting commitments, for no one likes to be forced to do something.

In the worst case, it might be necessary to design a system to work around non-participants. For example, because of open records laws, the non-participants must at least provide data in the form in which it is routinely used. This might make it possible to work around the reluctant individuals and still incorporate the necessary data, though not necessarily in the form that is most useful. This is not an ideal solution, but it can serve as a temporary measure until attrition and public or peer pressure alter the situation.

If upper-level management or elected officials are the reluctant parties, the best arguments are likely to be those centered around costs and benefits. Suggestions and details on benefit/cost study methods can be found in Chapter 15. It remains true, however, that much of the cost of an LIS is up front, in initial outlay for data automation or conversion, system design, hardware and software, and so forth. Many of the benefits, on the other hand, occur over longer periods of time and might not be easily measured. For example, what is the value of better, more informed decisions?

One possible strategy for allaying the fears of major budgetary impacts of an LIS and at least beginning the implementation process is a simple argument: "Growing evidence from other jurisdictions indicates that LIS is a cost-effective approach for land records management; the only way to know if this is true in this jurisdiction is to undertake a user needs assessment and a system requirements analysis."

Approval to conduct a needs assessment will likely result in the prediction of a positive benefit/cost ratio over the long term, which can be used to convince decision makers. There is always a chance, though, that a major step into automation might not be right at the present time. That is not necessarily a bad outcome of the needs assessment; it is still a contribution toward land records modernization. Through the critical examination of data sources and data management methods and the mandates surrounding spatial data use, a needs assessment will help offices manage spatial data more efficiently and effectively with manual methods too. Overall, it will have contributed to more thoughtful and rational use of information resources and, ultimately, to good government.

SUMMARY

There are many ways in which GIS hardware and software can enhance the efficiency and effectiveness of a modern multipurpose land information system. Automation can be an important component of an MPLIS, but technology alone is not a sufficient solution; institutional, organizational, and economic issues must also be addressed. In implementing an automated land information system in local government, several types of activities are typically found: for example, technology introduction, user needs assessment, system requirements analysis, implementation planning, and pilot projects.

In many situations, a "champion" is needed to initiate a land records modernization project and the technology introduction. That champion must educate two immediate groups: decision makers, who provide political and financial support, and technical staff, who will operate a system. The champion must ultimately reach a broader group of agencies and organizations, who will eventually use the system or share data. Careful choices must be made in the early stages of an LIS implementation about whom to include, how to organize them, and how to find out about their needs and resources.

The MPLIS concept requires significant institutional commitment and involvement. It involves much more than buying hardware and software and automating data. Perhaps the most critical aspects are people and organizations that must evolve and adapt to new methods. User needs assessment and system requirements analysis (see Chapter 16), later steps in the implementation process, are intended to probe deeply into how and why organizations manage and use land records. This in-depth examination could have other results, including recommendations for major changes in operating procedures and service delivery, in addition to the changes inherent in automation. An extensive and deep interest in and commitment to modernizing land records systems -- making them more efficient, effective, and accessible -- is necessary to successfully embark on this course of change.

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See Tables 14-3 and 14-4 for professional organizations and textbooks providing more information about automated land information systems.

Table 14-1: GIS SOFTWARE FUNCTIONALITY

User Interfaces

Command driven user interface
Pull-down or pop-up menu user interface
Icon-based user interface
Batch programs or command files for series of functions
Macro language or shell scripts for creating new commands
Source code or object code library for user program development
Tutorial or other method for self-instruction
An "undo' command to restore conditions prior to command
Recall of previous command(s) for re-execution
Logging of commands or operations
Soft error recovery
- user friendly error messages
- restore data files to original form
- remove scratch files

Data base management

Linkage of geographic data with attribute dbms
Facility for entering data quality information
Facility for recording data lineage
Facility for tracking transactions or updates
Access to attribute data
- direct - by attribute identifier
- direct - by selected geographic feature
- through relational key
- by natural language or SQL instructions

Ability to create, view, and manipulate meta data
Database operations
- sort tabular or graphic files by attribute or location
- calculate new values by arithmetic or logical expressions
- relate data files by common unique identifiers
- define rules governing behavior of data elements
- create, store, retrieve, and generate standard reports

Provision for organizing files by project
Generation of status reports on content and status of data base
Capability to add data files without regard to size or scale
System security
- password access protection
- electable read only or read/write access for different users

(Table 14-1 continued)

Computer network operation
  access common data file from file server
  data check out/check in procedure

Geographic Data Automation

Manually digitize two-dimensional point, line, or polygon data
"Snap-to" previously digitized features
Photogrammetrically digitized data incorporation
Coordinate geometry: protract lines, angles, and curve, intersect lines (create nodes), bisect angles, locate tangents, least-squares traverse adjustment, store curve as radius, arc endpoints, or center point, arc endpoints, offset parallel lines
Manually encoded raster (cellular) data: raster editing, thresholding and line thinning, raster to vector conversion
  scanned map data - raster
  scanned photographic or satellite data
Topological structuring
  manual assembly
  automatic (batch) assembly of polygons from lines
  automated calculations of area, length, perimeter

Data Editing and Error Correction

Attribute data association
  associate multiple attributes with geographic features
  assign attributes
  completeness check
  attribute range or value checks
  attribute format checks
Select features:
  by pointing
  based on attribute value
Insertion or deletion of selected geographic features
Cut and paste from update file
Interactive movement of individual points, lines, or areas
Interactive graphic annotation editing
Automated topological error reporting

Terrain and other 3-D Surface Representation

Contours
Regular gridded Z-values (digital elevation models)
Triangular irregular network (TIN)

(Table 14-1 continued)

Constrain contours by specifying barriers
Calculate cut or fill volume
Determine drainage networks or floodplains
Determine ridgelines or watershed boundaries
Determine viewsheds from user specified points
Compute slope and aspect values
Plot planar geographic features (terrain drape) over
  2.5 D net, wireframe, or contours
Plot geographic features or perspective view
  with shaded relief and hidden line removal

<u>Import/Export</u>

Arc/Info
AutoCad
DEM
DLG
ERDAS
ETAK
GIRAS
GRASS
Intergraph
MOSS
TIGER
Spatial Data Transfer Standard (SDTS)

<u>Data display and analysis</u>

Data Retrieval - select and display:
  by theme or layer
  within window specified by coordinates or reference map
  within window specified by on-screen digitizing -
  by feature names or groups of names
  by logical and Boolean retrievals on attributes
List attribute values of selected features
Report location of feature by pointing
Report straight-line distance or length by pointing
Report along-line-feature (network) distance by pointing

Data Restructuring
  raster to vector conversion
  vector to raster conversion
  map tile or sheet appending

(Table 14-1 continued)

automatic edgematching
line thinning or smoothing

Data Transformation
planar transformations
"rubber-sheeting" planar transformations
extract control point coordinates from master file
incorporation of USGS/NOAA projection package
incorporation of NOAA-NGS NADCON (or CORPSCON) datum conversion

Overlay
graphic superimposition
topological overlay
sliver removal
cross-tabulation
area weighted average

Networks
maintain line and node attributes
determine optimum path through network
determine optimum route for distribution through network
calculate optimum allocation or collection zones

Other Geoprocessing
buffer
proximity report
nearest neighbor
dissolve
automated address matching
adjacency

Data Display and Information Product Creation

Data Display:
generate graphic displays (on screens, plotters, etc.)
display vector data with raster (image) backdrop
generate hardcopy output to plotters, printers, filmwriters, etc.

Information Product Creation:
compose products interactively
compose products with command files or map templates
store, retrieve, and re-display compositions
user specified scale, orientation, map size, and location on sheet

(Table 14-1 continued)

display point, line, and polygon data sets
display map features: neat lines and grid lines graticules
create and position: scale bar, legends or keys, north arrow,
map titles, logos, and single or multiple line text
interactively position map elements
ability to select point symbols, line types, and area fill patterns
ability to create, name, store, and select new point symbols,
line type, and area fill pattern tables
ability to assign by attribute, selection, or lookup table
automatically position text at pre-specified point location
ability to specify individually for any text string: font, case, size, spacing, color, angle, and curvature

Source: Modification and Enhancement of FICCDC, 1988.

Table 14-2: ELEMENTS OF AN LIS IMPLEMENTATION PLAN

Work plans:	Which tasks are necessary for system operation? Which optional tasks will most enhance system capabilities?
Timelines:	By when should designs and plans be completed and approved? When should tasks be completed? When is equipment and outside data expected to arrive?
Staff responsibilities:	Who is responsible for carrying out tasks, project management, system maintenance and backup, security, vendor liaison, consultant liaison, budget liaison, training, etc.?
Training:	Who will receive initial training in various aspects of the system, including hardware maintenance, system management, and software programming? How will new users be trained?
Data automation:	What sequence of automation will yield system benefits in a reasonable time frame? Which data automation methods (e.g., digitizing, scanning, and COGO) are appropriate for which source materials? What data are already automated? Who has the data and what will have to be done to convert them?
Application development:	Which applications have a high likelihood of early success? Which application priorities will be impacted by events outside the control of the implementor?
Workspace arrangements:	Where will equipment go? Are there special requirements in terms of environmental conditions, air-conditioning, or power sources?
Collection and handling:	What kind of document control procedure is needed of source materials?
Quality control procedures:	What consistency checks should be established? What are the standards for various processing steps?
Equipment and software:	Does equipment and software do all that is claimed? Does it fulfill the needs for testing and evaluating our applications? If the software is being added to an existing platform, what will the effect on existing operations be?
Backups:	How often should they be done? On what media? Using what procedure?

(Table 14-2 continued)

Database maintenance:	What procedures and sources will be used to update the data base with new information? How will files be organized and accessed?
System and equipment:	Are measures required such as passwords, read-only protection, locks, and security clearances? Have all types of security been considered: physical security (theft, vandalism, power problems, "acts of God", etc.), data base security (access), and data element security (authorization)?
Cost and time audits:	How do we account for time and effort in system construction and maintenance?
Alternative and fall back:	What are the contingency plans if tasks cannot be completed?
Continued interaction:	How will we respond to new application developments? How can we assure with technical experts that system capabilities remain dynamic?
System review:	How often should we audit the performance of the system? Which aspects should be reviewed? What outside reviews are expected? Are there regulatory approvals needed?
Modification procedures:	How can we incorporate the results of performance evaluations into system and feedback loops evolution?

Table 14-3: NATIONAL PROFESSIONAL ORGANIZATIONS WITH LIS ACTIVITIES

American Congress on Surveying and Mapping (ACSM)
5410 Grosvenor Lane, Suite 100
Bethesda, MD 20814-2122
phone: (301)493-0200; fax: (301)493-8245

American Society for Photogrammetry and Remote Sensing (ASPRS)
5410 Grosvenor Lane, Suite 210
Bethesda, MD 20814-2160
phone: (301)493-0290; fax: (301)493-0208

AM/FM International
14456 East Evans Avenue
Aurora, CO 80014-1409
phone: (303)337-0513; fax: (303)337-1001

Association of American Geographers (AAG)
1710 16th Street, N.W.
Washington, DC 20009-3198
phone: (202) 234-1450; fax: (202) 234-2744

International Association of Assessing Officers (IAAO)
1313 E. 60th Street
Chicago, IL 60637
phone: (312) 947-2064

National Computer Graphics Association (NCGA)
2722 Merrilee Drive, Suite 200
Fairfax, VA 22031
phone: (800)225-NCGA or (703)698-9600; fax: (703)560-2752

Urban and Regional Information Systems Association (URISA)
900 2nd Street, N.E., Suite 304
Washington, DC 20002
phone: (202)289-1685; fax: (202)842-1850

Other organizations that occasionally offer materials of interest:

American Planning Association
1776 Massachusetts Avenue, N.W.
Suite 704
Washington, DC
phone: (202)872-0611

(Table 14-3 continued)

American Public Works Associations
1313 E. 60th Street
Chicago, IL 60637
phone: (312)667-2200

National Association of Counties
440 First Street, N.W.
Washington, DC 20001
phone: (202)393-6226

Soil and Water Conservation Society
7515 N.E. Ankeny Road
Ankeny, IA 50021
phone: (515) 289-2331

North American Cartographic Information Society
6010 Executive Boulevard, Suite 100
Rockville, MD 20853
phone: (301)443-8075

Table 14-4: BOOKS ON LAND AND GEOGRAPHIC INFORMATION SYSTEMS

Aaronoff, Stan, 1990: Geographic Information Systems: A Management Perspective, WDL Publications, Ottawa, Ontario.

All, Kathleen, Green, Stanton, and Zubrow, Exra, editors, 1990: Interpreting Space: GIS and Archaeology, Taylor and Francis, New York, NY.

Antenucci, John, et. al., 1991: Geographic Information Systems: A Guide to the Technology, Van Nostrand Reinhold, New York, NY.

Burrough, P., 1987: Principles of Geographic Information Systems, Addison-Wesley Press, New York, NY.

Dale, P., and McLaughlin, J. D., 1988: Land Information Management, Oxford University Press, New York, NY.

GIS World, 1989 and 1990: "The GIS Sourcebook," GIS World, Inc., P.O. Box 8090, Ft. Collins, CO 80526.

Guptill, Stephen, editor, 1988: "A Process for Evaluating Geographic Information Systems," USGS Open File Report 88-105, U.S. Geological Survey, Reston, VA 22092.

Huxhold, William E., 1991: An Introdiction to Urban Geographic Information Systems, Oxford University Press, New York, NY.

Langran, Gail, editor, 1992: Time and the Geographic Information System, Taylor and Francis, New York, NY.

Onsrud, Harlan, and Cook, David, editors, 1990: Geographic and Land Information Systems for Practicing Surveyors: A Compendium, American Congress on Surveying and Mapping, Bethesda, MD.

Ventura, Stephen J., 1991: Implementation of Land Information Systems in Local Government - Steps Toward Land Records Modernization in Wisconsin, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Rd., Madison, WI 53705.

Vonderohe, Al P., Gurda, Robert F., Ventura, Stephen J., and Thum, Peter G., 1991: "Introduction to Land Information Systems for Wisconsin's Future," State Cartographers Office, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Rd., Madison, WI 53705

Table 14-5: LOCAL LAND RECORDS USERS

County and municipal offices or functions

- Taxation/Assessment
  - Real property lister
  - Abstractor
  - Assessor
  - Clerk
- Register of deeds
- Landmarks Commission / Historical Society
- Surveyor
- Zoning administrator / Zoning inspector
- Public works
  - Water and sewer
  - Gas and electric
  - Transportation
  - Storm drainage
  - Engineering
  - Waste management
- Conservation
  - Agricultural Extension Services
  - County Forest Manager
  - Soil and Water Conservation District
- Planning
- Community development
- Recreation / Parks
- Building inspection / Permits and licenses
- Public safety (emergency services, fire, police, rescue)
- Data processing
- Sanitarian / Health officer

State Departments (including regional offices)

- Natural Resources/Environmental Protection
- Transportation
- Revenue
- Administration
- Agriculture, Trade, and Consumer Protection
- Justice
- Development
- Labor
- State Cartographer/State Surveyor or other NCIC affiliate
- Geological or Natural History Survey

(Table 14-5 continued)

Planning
Universities (e.g., departments of Geography, Civil Engineering, Computer Science, Forestry, Landscape Architecture, and Planning)

Regional and special districts

Registrar of voters
School districts
Sewerage districts
Regional planning commissions
Watershed associations

Federal

Environmental Protection Agency
Federal Emergency Management Agency
USDA Soil Conservation Service
USDA Agricultural Stabilization and Conservation Service
USDA National Forest Service
USDI United States Geological Survey
USDI Fish and Wildlife Service
USDI Bureau of Land Management
USDC Bureau of Census
USDC NOAA National Geodetic Survey

Private

Board of Realtors
Title insurance companies
Timber corporations and other land holders
Consulting engineering firms - surveying, photogrammetry, mapping, GIS
Appraisers
Land-holding conservation organizations (e.g., Nature Conservancy)

Utilities
Gas
Electric
Water
Cable television
Telephone
Digger's Hotline services

APPENDIX 14-1
PRELIMINARY DATA INVENTORY AND POTENTIAL USER SURVEY FORMS

The preliminary questionnaire (example shown on page 14-39) is one of the two types of user needs assessments. It is usually a brief mail survey broadly cast to all potential system participants. Its purpose is to get:

- an initial assessment of who might be interested in participating in a multi-agency information system

- a general idea of what kinds of data they use and information needs they have

- what they might be able to contribute in terms of resources such as staff time, expertise, equipment, etc.

A cover letter from a prominent official can enhance response rates. Many jurisdictions have followed the survey with a general meeting to explain results and outline in a general way what they hope to accomplish.

(Appendix 14-1: Form 1)

Multipurpose Land Information System
Prospective User Survey

Name ______________________ **Position** ______________________
Department ______________________ **Phone** (______)______________
Company or Community ______________________________________

Land Related Data Production

1) Does your agency create any new maps (e.g., parcel maps)? Y N

If yes, briefly describe______________________________

2) Does your agency compile data on existing maps (e.g., zoning maps)? Y N

If yes, briefly describe______________________________

3) Is your agency responsible for assigning spatial identifiers - *geocodes* (e.g., parcel identification numbers, well identification numbers) Y N

If yes, briefly describe______________________________

4) Does your agency create or compile data directly tied to maps or geocodes (e.g., farm conservation plan, assessed value)

If yes, briefly describe______________________________

5) Are any of the above land related data automated (in digital form)? Y N

If yes, briefly describe______________________________

6) Which of the above activities are required by legal mandates?

7) Which are done primarily for internal information needs and client services?

8) List (or attach) any available written reports that describe your data production methods, data quality evaluation, or data access policies.

9) List other organizations that access or obtain the data you produce.

(Appendix 14-1: Form 2)

Multipurpose Land Information System
Prospective User Survey

Land Related Data Use

1) What land related data does your agency access and use on a regular basis (for example, assessed value, soil type, easements)? In what form do you generally get the data (e.g., maps, tables, printouts, digital)? Who produces the data?

DATA	FORM	SOURCE

2) Which of these data forms must be further processed to be useful for your agency or its clients? List any sources from which data are substantially changed or enhanced and the final form of the information product that your agency uses.

DATA	INFORMATION PRODUCT

3) What land-related data does your agency access and use occasionally? In what form do you generally get the data (e.g., maps, tables, printouts, digital)?

DATA	FORM	SOURCE

4) List any of the above data sources that you are not satisfied with and why (e.g., not accurate enough, not readily available, not current)

DATA	PROBLEM

(Appendix 14-1: Form 3)

Multipurpose Land Information System
Prospective User Survey

Automation of Land Records

1) Which of these terms are you familiar with?

   __ geographic information systems (GIS)
   __ computer aided drafting (CAD)
   __ automated mapping and facilities management (AM/FM) systems
   __ national geodetic reference system
   __ global positioning system
   __ data "custodians"

2) Does your agency have any automated land information?

   __ tabular data software:________________________
   __ CAD software:________________________
   __ GIS or AM/FM software:________________________

(If you checked any of these, skip to question 6)

3) Is your agency considering an automated land information system in the future? Y N

4) Do you think an automated land information system could help your agency better manage the land-related information that it uses? Y N

5) Would you like someone to contact you and provide more information about automated land information systems? Y N

6) Would your agency be interested in participating in a county-wide multipurpose land information system? Y N

7) Which of the following resources might you be able to contribute to a system (this is not a commitment; it is for general information only):

   __ funding __ equipment or software

   __ technical expertise __ training

   __ data sharing __ staff time (for automation or operations)

   __ policy committee __ design and implementation committee

   __ other (please specify)

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS SURVEY

15 ECONOMICS OF MPLIS: CONCEPTS AND TOOLS

D. David Moyer

INTRODUCTION

Economics is a social science that permeates many aspects of our daily lives. Economics impacts our individual households, the agencies or companies for which we work, our nation, and more recently, the entire world. Thus, economics affects each one of us in many ways.

Economics also provides us with tools and a framework for use in evaluating many alternatives about which we must make decisions. This chapter focuses on the use of economic tools that are relevant to the evaluation of various aspects of MPLIS systems. Thus we can use economics to:

- examine land information and land information systems in general,
- evaluate a new MPLIS that is being considered for implementation,
- compare two or more MPLIS alternatives,
- compare current modes of operation with the MPLIS approach, and
- evaluate individual projects involving the use of MPLIS, whether manual or automated.

This chapter is divided into three sections. The first section considers the general field of land information system economics. This section attempts to provide a broad economic framework for the later sections. Therefore, a number of concepts are examined, including supply and demand of information, production functions, marginal cost functions, impact of technology, supply and demand, and joint products.

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The second section turns to a specific tool, benefit/cost analysis (BCA), that is widely used in the evaluation of government projects of all sorts, including MPLIS systems. The section defines BCA, discusses how it is used and the kinds of results (help) it can bring to the decision maker, and finally, outlines a number of caveats with which the user of BCA should be aware.

Section three presents a number of examples from the literature of economic evaluations of LIS/GIS. The section provides information on approaches used, as well as results obtained.

ECONOMICS OF LAND INFORMATION SYSTEMS

The purpose of this section is to provide a broad framework for the discussion of the economics of MPLIS systems. Therefore, we begin with a number of concepts and terms that are relevant to our later discussion.

There are at least two basic uses for information economics in the discussion of MPLIS systems:

1. Information economics helps provide an understanding of the development, maintenance, and use of MPLIS. That is, the successful design of an MPLIS depends on an understanding of the value and cost of land information and LIS.

2. It also provides ideas on concepts and approaches that can be used in justifying an MPLIS and selling it to the administrators and other decision makers in your organization. For instance, information economics is not only about the cost of building a MPLIS system, or the savings that such a system will provide, compared to current manual methods. Rather, while information economics is useful for the above uses, it is also important in understanding and evaluating the impact of changes in the way the organization does business, since this is really the long-term impact of the effective introduction of an MPLIS system into an organization.

DEFINITIONS AND CONCEPTS

Before turning to details on information economics, we should note several definitions and concepts that are important to this discussion.

An MPLIS was defined earlier as the hardware, software, data, people, and institutional and organizational structure needed to collect, edit, store, analyze, retrieve, and output land information. Data in the system are arranged systematically in order to facilitate accessibility by users, as well as consistency of the data base and outputs created from it. Other features of an MPLIS include precision, accuracy, refinement of definitions (e.g., what is a parcel?), completeness, currency, frequency, and flexibility. Each of these features or characteristics influences the design, operation, and resultant economics of the MPLIS. For example, greater accuracy of data will usually increase the cost of the MPLIS, but it will also often increase the use of the system as well. This increased use can produce new benefits for existing system users, as well as generate new users of the system. Since system costs will then be spread over a wider user base, thus producing greater benefits, the additional costs for improved accuracy are often more than offset by increased benefits to users of the system.

Decision Framework

Decisions regarding MPLIS made by local and state governments are related, by and large, to existing information functions. The governmental agencies involved already have legally defined responsibilities related to land information. They also have the means to fulfill these responsibilities. (They may not be able to do the job as quickly as they or their customers would like, and the resulting output may not be as refined as would ideally be the case, but required results are generally produced.) Government workers rely on standard forms, statutory, administrative rule, or historical precedent, files that have been created for convenience, and numerous "make do" adaptations that have been created to get the job done. This means that the implementation of an MPLIS almost always means changing or replacing an already existing system. We seldom have the luxury of starting a city, county, or state LIS system from scratch (Wunderlich and Moyer, 1986).

Data and Information Distinguished

Information is data that has been put in context. That is, information is data that has been processed or transformed in order to meet a particular need. Economics tends to narrow the definition of information still further, defining information as the reciprocal of uncertainty. Thus, the more relevant information we have about a particular situation or item, the less uncertainty (more reliability) that exists. Therefore, it is possible to treat information as a goods or service that has value because of the ability of additional units of information to reduce uncertainty. Figure 15-1 illustrates this relationship between information and uncertainty.

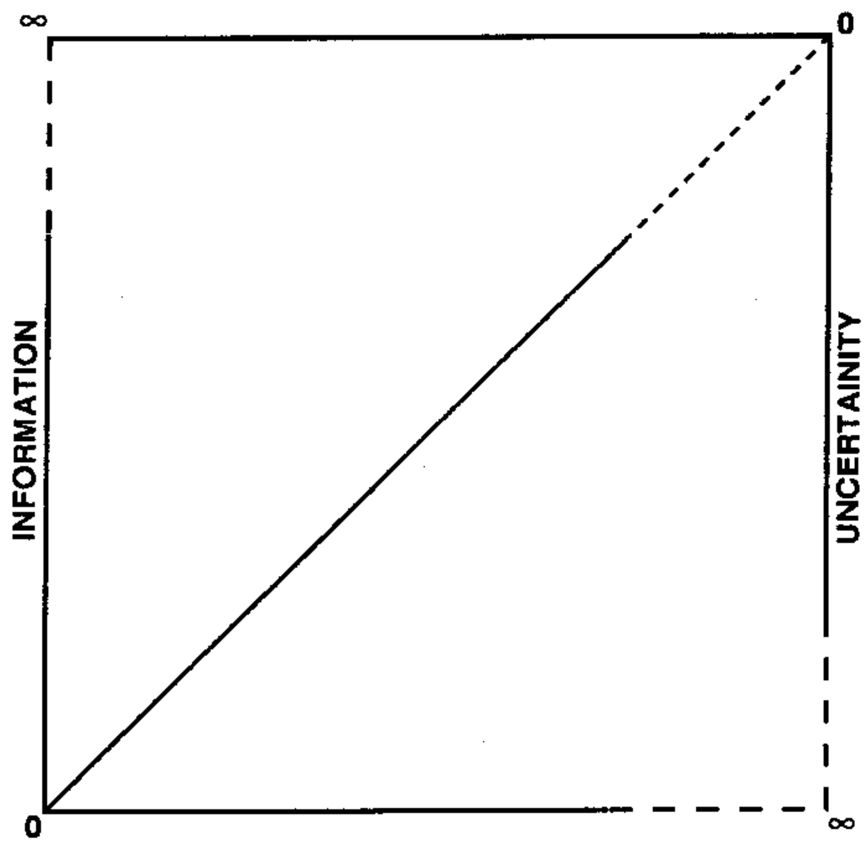

Figure 15-1: Information Vis-a-Vis Uncertainty

As an example, consider the information/uncertainty involved in defining the size, shape, and location of a parcel of land. A surveyor prepares a description of the parcel by using various equipment, field techniques, previous records, training, and traditions in the geographic area of interest. Depending on the client's needs and resources to pay for the service, the surveyor may prepare a simple sketch for a mortgage survey, use a theodolite or even GPS to determine coordinates of property corners, angles, and distances, and tie the parcel description to a plat, city plan, or even a statewide, nationwide, or worldwide coordinate system. Each additional relevant piece of information will decrease the uncertainty about the parcel description. The level of accuracy will also affect the information content (and cost) of the survey (for example, a survey with a closure accuracy of 1:3,000 will contain less information and be less costly than a 1:50,000 or 1:100,000 closure survey).

PRODUCTION FUNCTIONS

A conventional production function is displayed in Figure 15-2. This curve indicates that as inputs (e.g., time, money, effort) are increased, we obtain less and less increase in output. This is often referred to as the law of diminishing return, since each additional unit of input produces a smaller and smaller increase in output. Also, this figure suggests that it is possible to approach, but never actually reach, the state of complete information.

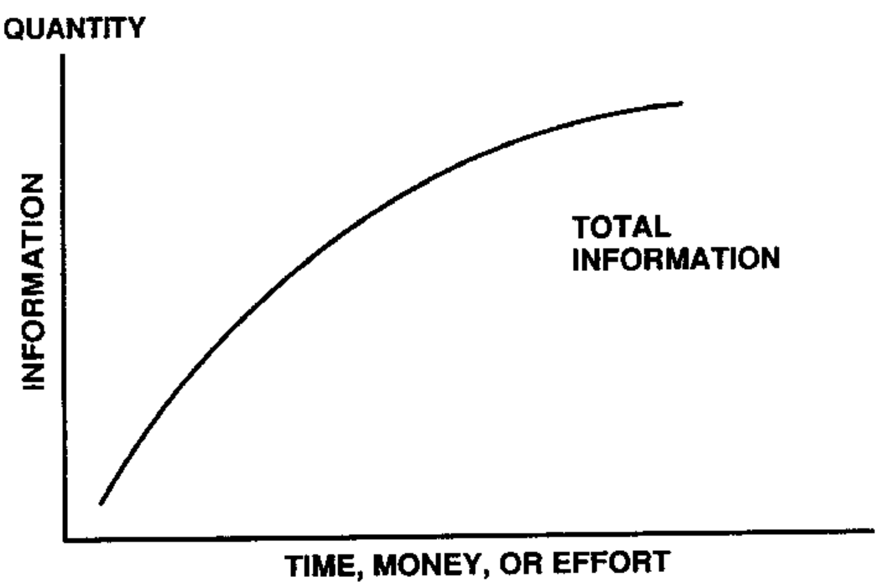

Figure 15-2: Information Production Function

The process we use in the United States for the evaluation of quality of title exemplifies the process of approaching, but never reaching, a point equal to full information. The U.S. title system depends on the recording of evidences of title, not the title itself. Therefore, the title evaluation process requires that we collect as much of this evidence as we want or are willing to pay for. In this title examination process, the reduction of uncertainty almost never reaches the zero point (e.g., see Figure 15-1). In economic terms, the best title is not necessarily the one with all uncertainty removed, but rather the one about which all uncertainty worth searching for has been removed. For example, it makes "economic sense" to search for information until the savings from the last unit of information obtained just exceeds the cost of obtaining the information.

Similar illustrations can be made for survey maps, assessment records, or as-built highway or building drawings. In each case, more effort, time, or money will likely produce more accuracy, more detail, or more timely information. The economic issue that must be faced is what cost, in terms of dollars, time, or effort, is the user willing to pay for these marginal increases in inputs in order to obtain more, or higher quality, output. Also, in MPLIS, it must be kept in mind that different users and different purposes are likely to have different requirements. Economics can help in these instances by helping to determine what the additional costs are and suggest how these costs might be allocated to users.

MARGINAL COST FUNCTIONS

Another way to consider (and plot) these changes in production due to increased inputs is to examine only the marginal changes in cost and production. Thus in Figure 15-3, the first

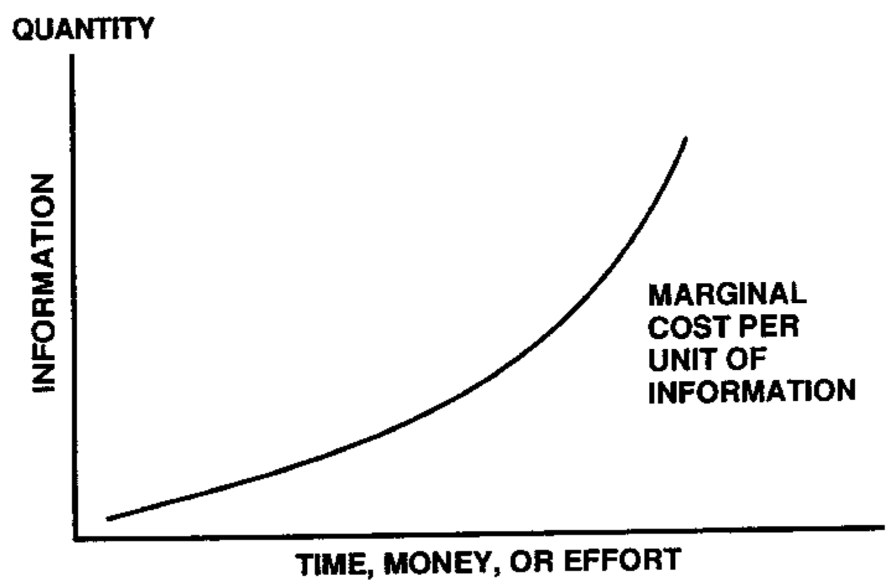

Figure 15-3: Marginal Cost Function for Information

additional units of output cost relatively little (i.e., the curve rises only slightly at the beginning as we move to the right). Subsequently, as we move further to the right, each additional unit of output costs more and more (in time, dollars, etc.), and the curve soon is nearly vertical.

Understanding and use of production functions can be useful to both designers and users of MPLIS systems. However, it must be noted that to create such functions, it is necessary to specify (or find proxies for) output units of information, measures for inputs such as effort and time, and make comparisons between alternative production functions.

IMPACT OF TECHNOLOGY

Comparison of alternative production functions arises, for instance, due to the development of new technology. New technologies for handling land information can revolutionize access to data, producing large increases in both the number of users and the uses to which the information is put.

Computerization of property assessment records permits the use of computer assisted mass appraisal (CAMA), which radically changes our ability to aggregate assessment data, manipulate these data for assessment and other uses, and makes possible the access of these data by a much larger group of users.

Changes resulting from new technology are represented graphically in Figure 15-4. Status quo is represented by the solid curve, while introduction of new technology causes a shift to the "dashed" curve. Two types of shifts are illustrated: increases in output and savings in inputs. The creation of digitized information on physical features of land has greatly enhanced the opportunities for planners to create and consider optional designs for land development (WLIN, 1983). Computer assisted appraisal now allows annual reassessment of parcels, many of which were only changed at 5-, 8-, or 10-year intervals when manual assessment was used. CAMA systems have greatly reduced manual labor of repetitive entries into record files and indexes. Microfilming, digitizing, and image processing have reduced the physical space needed for record storage, as well as making these records more easily accessible to a much larger audience. The net result is major shifts in the production, cost, and use of many kinds of land information.

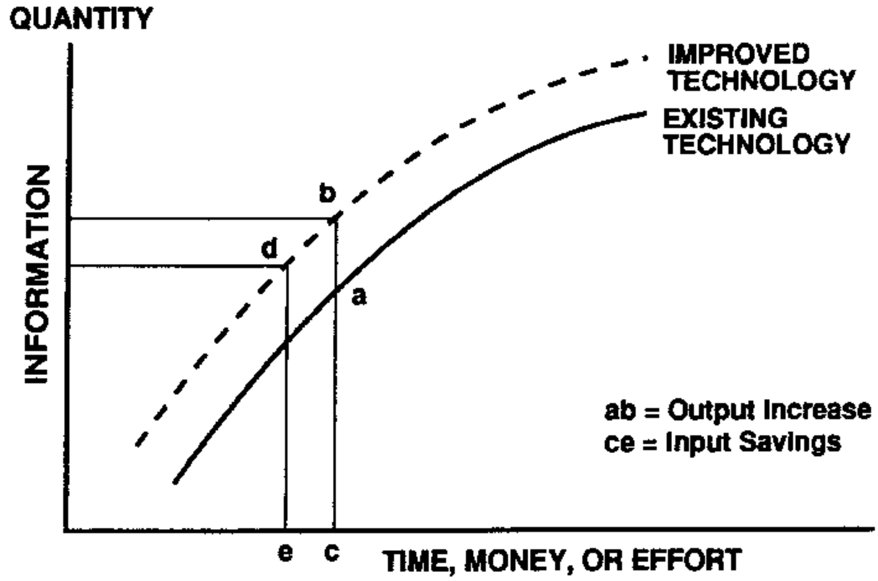

Figure 15-4: Impact of Technology on Information Production Function

SUPPLY AND DEMAND

Four concepts or assumptions provide the foundation for the discussion of supply and demand of land information:

1. Information has value.
2. People want information.
3. Information is limited in amount.
4. Information is made available at a cost.

These concepts are useful in the general examination of MPLIS.

The "market" for land information is a far cry from the classical free market mode. Problems such as poorly defined units of information, lack of precise terms of exchange, and the impact of regulations and fee structures all tend to make it difficult to determine the slope and shape of demand and supply curves for land information. Nevertheless, supply and demand concepts help provide a framework for a discussion of the various costs and benefits of land information and land information systems.

Figure 15-5 contains several examples of typical demand curves (functions) that exist as to land information. Note that as the price, P, of land information (on the vertical axis) drops, we can expect the quantity of land information demanded to increase.

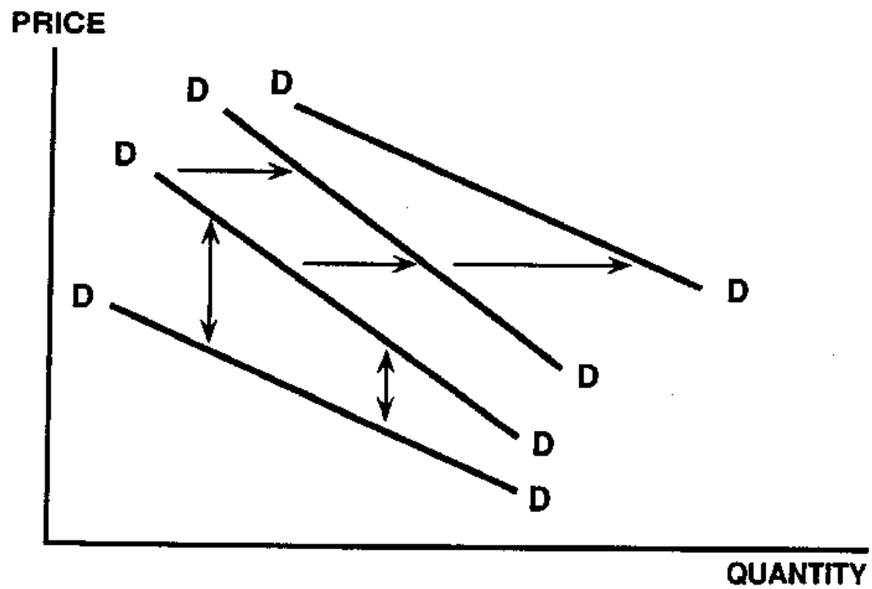

Figure 15-5: Information Demand Functions

Similarly, the supply curve in Figure 15-6 suggests that more information will be provided when more dollars are made available to pay for it (i.e., when the price increases). These concepts thus can be used to help users determine what land information they really want to request, and also, to help providers decide what land information they will provide, given the price they can realistically expect to receive for it. Therefore, economic analysis can be useful if it can provide even rough estimates to guide users and producers in this decision making process. For

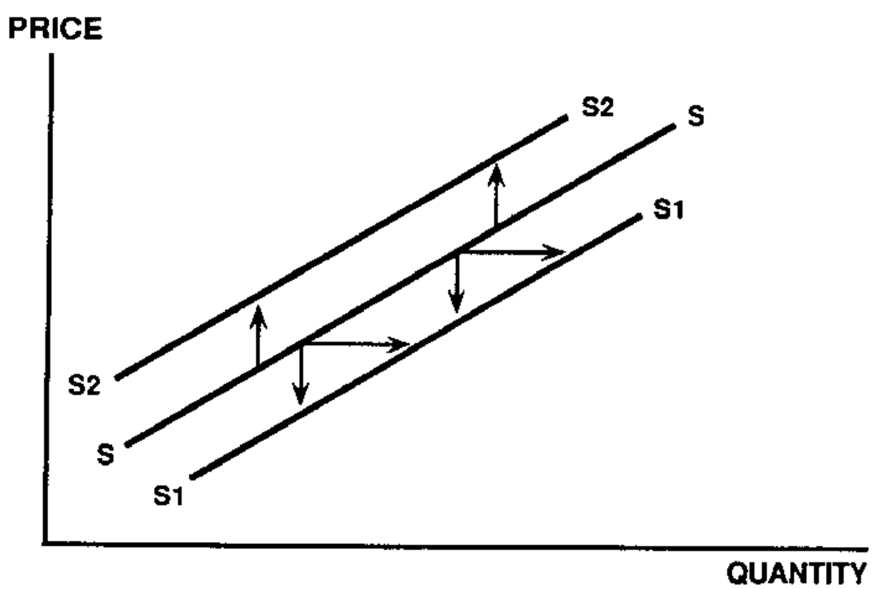

Figure 15-6: Information Supply Functions

example, how much more assessment information will be used if we can cut the access time (an important cost) by 25 or 50 percent? Similarly, how many new tables or new maps would be produced if demand, as evidenced by willingness to double the expenditures for such products, became apparent?

Thus far, we have considered the shape and slope of supply and demand curves as related to information. In many cases, the shifts and changes affect relationships between supply and demand. For example, new uses of title or tax record information may shift the demand for information to the right (Figure 15-5). New technology, in the form of LIS software or computer hardware, may increase capital costs, but also lower the time and effort for public officials and other users. The net result is a downward shift in the supply curve (Figure 15-6). If automation results in the capability to produce more information at a given cost, the supply curve can shift to the right (Figure 15-6). The use of scanning technology to capture certain types of graphic data for use in an MPLIS is one example of the supply curve shifting to the right. Use of scanners has been found to produce a three-fold increase in output of soils data for a given level of inputs (time and cost) (Moyer and Niemann 1990). Comparable shifts have been documented through the use of Global Positioning System (GPS) technology for determination of coordinate locations for survey monuments (ibid.).

Industry-wide demand and supply relationships can provide important insights into the land information "business." For example, the demand for GIS/LIS products in the United States over the 8 years from 1992-1999 is estimated to total $100 billion (*The Economist*, 1992). A demand of this magnitude will have major impacts on the equilibrium quantity supplied, as well as the shapes of the supply and demand curves. Similarly, new technology has, and will continue to have, a major impact on the information "market." For instance, $10,000 workstations of today have the capabilities of $250,000 mainframe computers of the mid-1980s, a 96 percent reduction in cost. Comparable improvements in technology appear likely to continue to occur.

Probably even more important in planning and evaluating an MPLIS for a specific jurisdiction is to focus on the demands and supplies that are likely to result from specific classes of users. The needs (demands) of planners, assessors, and title conveyancers, compared to the output (supplies) provided by recorders and title insurers is more manageable and probably more useful when evaluating a jurisdiction-specific MPLIS.

It is also important to consider demand and supply of information at each stage of production. For example, an assessor is a user (demander) of information from other local officials for some parts of the assessment process. The assessor is also a supplier of information to other officials, such as treasurers, private appraisers, and taxpayers, at other times. By setting up the analysis in this way, it is easier to carry out the evaluation, and it usually produces a result that is more pertinent to the local situation.

JOINT PRODUCTS

Two or more offices, agencies, or other user groups sometimes work together to produce a product that is needed by all members of the producing group. The economies resulting from the production of these products jointly can be credited as benefits of an MPLIS. Caution should be used when valuing joint products, since such economies are typically more often claimed than actually demonstrated (Wunderlich and Moyer 1984). However, there are a number of examples of economies resulting from such joint product efforts.

1. Reduction in duplicate map sets: Albuquerque reduced the number of map sets maintained by the city from seven to one.

2. Specialization of knowledge: Title insurers have specialized in the compiling of data and production of information about the quality of land titles. This specialization produces information that now produces income for such companies of several billion dollars annually. This information is generally of higher quality, cheaper, and more accessible to the user public than data in the public record system maintained by counties.

3. Added value resulting from the combination of separate data elements: By combining ownership data and soils data, the resulting information is more useful for value assessment and for producing soil erosion reduction plans [in Wisconsin].

4. Efficiency in data processing: As computers (hardware) become faster, less time is needed to access programs (software) and load data bases, which saves time for the operator as well as saving computer time.

5. Coordinated outlets for information products and services: Users of MPLIS systems save time, frustration, and error by having access to a one-stop system for access to land information (e.g., building permits).

One final aspect on joint products should be noted -- some tradeoffs may be necessary to produce these products. For example, compromises may be necessary as to levels of precision, ease of access, currency of data, and frequency of updates. Any losses (costs) as to these items, for specific offices or for specific functions, must be measured against overall gains (benefits) that accrue to the MPLIS in general.

BENEFIT/COST ANALYSIS

One of the tools that is widely used in the economic evaluation of public sector projects and systems is BCA. This section examines the economic nature of information, what BCA is and how it is used, the complexities of BCA, the kind of help it can provide to decision makers, and outlines several caveats that should be kept in mind when applying BCA to specific information system situations.

ECONOMIC NATURE OF INFORMATION

In any sector of our economy, we can point to scarcity -- of dollars, people, or time -- that affects the output of goods and services. In order to make decisions regarding the economy, (e.g., how to carry out a job most effectively or whether to do one task as opposed to another), we need to collect and organize information to help make these decisions. This is true whether our role is policy maker, bureaucrat, or private consumer.

Economic evaluation techniques can provide a number of answers to questions that are often raised when MPLIS systems are competing for resources. Questions include:

- How much will the new system cost to implement?
- How much will the new system cost to maintain?

- What cost savings will it produce (e.g., what current tasks will it replace)?
- What additional benefits, besides cost savings will the MPLIS produce (e.g., what new products will it produce and what is their value)?
- How does the MPLIS compare with other systems and projects that are competing for dollars in this budget framework?

A number of techniques, including BCA provide a rational framework for providing the answers to such questions in a dollars and cents context that is relatively easy to understand.

For products in the private sector, "markets serve as the decision making mechanism for deciding what will and will not be produced" (Epstein and Duchesneau 1984). Also, these markets help determine the amount that will be produced (and demanded) and the price at which products will be bought and sold.

In this private market situation, benefits are reflected by the willingness of consumers to make expenditures in order to buy and consume various amounts of a product or service. Similarly, expenditures "are reflected by the schedule [production function curve] of costs incurred at various levels of output" (ibid.). The interaction of these benefits and costs in the market establishes the price or value of the product in question. Resources are then allocated by supply and demand forces, as discussed above. Markets, and the prices that operate within them, thus provide a mechanism for determining the benefits and costs of alternative users for scarce resources. Both the producer and the consumer are thereby guided in their decision making by the information they receive from the market.

Unfortunately, traditional markets do not provide much help when it comes to valuing information and information systems. The market is not directly applicable to most situations that involve government (and other public sector) products and services. This conclusion is based on several assumptions, all of which are related to the economic nature of information:

1. Public goods are consumed collectively. Governmental products (public goods) are consumed collectively by society as a group, while private goods are usually consumed by individuals. This consumption "pattern" for public goods results because no one can be excluded

from consuming a public product, once it is produced. (Items such as national defense, the Interstate Highway system, and survey monuments are typical examples of public goods that are "available to all consumers.")

2. Public information is a public good.

3. Public information is not sold in a traditional market.

4. Value of information is determined by its contribution to decisions.

5. People will pay for information that reduces risks associated with decisions that they must make.

6. The search is not necessarily for the best information, but for the best information worth searching for.

This last point is obvious when considering the evaluation of the quality of a land title or collecting information about the value of a land parcel. The cost of collecting all information about a land title would be very expensive. In many cases, the acquisition of all information is not possible, even if resources to do so are unlimited. Therefore, the tradeoffs of greater certainty about title quality are almost always compared with the cost of acquiring more information about the title.

What all this means is that some alternative, non-market method of resource allocation is needed in regard to public goods, such as land information or MPLIS systems. BCA is one approach that is often used to help in decision making in the public sector. That is, BCA in the public sector replaces the function served by the market in the private sector.

DEFINITION OF BENEFIT/COST ANALYSIS

Important points about BCA include the following.

1. BCA is a means to organize ideas and structure the decision process.

2. BCA forces a consideration of both quantifiable and non-quantifiable factors in public expenditure decisions.

3. BCA is not a substitute for making decisions, rather it is a tool to provide help in this process.

The basic idea in a BCA is to determine if benefits exceed costs. This involves adding up all costs and all benefits and comparing them. This comparison is typically carried by determining the benefit/cost ratio, i.e.,

$$\frac{\text{Sum of all Benefits}}{\text{Sum of All Costs}} = \text{B/C ratio}$$

If the ratio is greater than 1 (i.e., if $B > C$), the project, system, or service is considered to be cost effective.

While BCA is simple in concept, it becomes much more complex when actually applied to a specific situation. Identifying all impacts that result in costs and benefits, placing a value (or weight) on each item identified, and comparing the sum of benefits with the sum of costs is almost never a simple procedure.

COMPLEXITIES OF BCA

Identifying the Impacts

There are a number of reasons for the operational complexity of BCA. First, all of the benefits and costs of the activity must be identified. It is usually relatively easy to identify direct impacts, such as income from products, costs of new hardware, labor to operate the system, and cost-savings from termination of the activity replaced. However, the indirect impacts are, by definition, much harder to identify. Indeed, the decision-making process often becomes more difficult due to this aspect of BCA, since a larger number of relevant factors are identified for consideration than would otherwise be the case.

A classical BCA should include all impacts that apply, regardless of where in society they occur. However, in actuality, many impacts are not included. These excluded impacts are outside the framework within which the decision maker is operating. These excluded impacts are often termed externalities. The following examples are illustrative of the restrictions that are sometimes applied to BCA.

a. A soft drink bottler evaluates the benefits and costs of switching from returnable to non-returnable bottles. The bottler compares the cost of producing new, non-returnable bottles each time, versus the cost of collecting and cleaning the returnable bottles. Based on a lower cost for producing new bottles each time, the bottler chooses the non-returnable option. The shortcoming in this analysis is that the benefit/cost equation was not complete, since the external effects of the societal costs of disposing of the bottles (in landfills or recycling), are not included in the decision-making process.

b. A government agency evaluates the benefits and costs, within their agency, of using GPS (Global Positioning System) to develop a geodetic survey network to support engineering work in their agency. Since the benefits exceed costs, the agency approves and implements the system. The shortcoming here is that if other agencies and the private sector had been included (i.e., if "the net had been cast wider"), an even more favorable benefit/cost ratio would have been obtained. (While costs of including others would have increased the costs, the benefits of such a multi-agency effort would have increased even faster.)

Valuing the Impacts

A second operational complexity of BCA arises due to the need to assign a weight (or value), to each impact identified. Some effects, such as increased output, decreased costs, less space, fewer employees, more hardware, and new software, are relatively easy to weigh. Other impacts are more difficult when their impact is secondary or tertiary, being relatively far removed from the decision that is being made. For example, how do you weight the impact on the national mortgage market due to the reduced title transfer costs that result from title insurance or automated title record systems in county government?

Other approaches have been suggested for valuing the impacts of GIS use. One such approach involves a three-step process (Gillespie, 1991):

1. Identify how outputs have changed.
2. Identify how each change in the output affects the users.
3. Determine the value of each effect on the users.

This technique is suggested to be especially useful in valuing benefits that occur as a result of being able to do tasks with the MPLIS that were not possible using manual methods.

Accounting for Temporal Differences

A third difficulty in carrying out a BCA is that costs and benefits do not occur all at one time. More often costs and benefits, especially the latter, tend to occur as a stream over a period of time. This is particularly true for benefits, which often accrue over 5, 10, or 20 or more years. Costs, on the other hand, tend to be "front end loaded," occurring early in the project (see Figure 15-7).

The "total cost" curve in Figure 15-7 shows that there are substantial costs at the very beginning of LIS development. Also, benefits do not start occurring immediately; rather they are delayed until the system has been in operation for several months, a year, or longer. By tabulating total costs and total benefits, a breakeven point, where total project costs are equal to total project benefits, can be obtained. In many LIS projects, this breakeven point occurs about 5 to 7 years after initiation of the project.

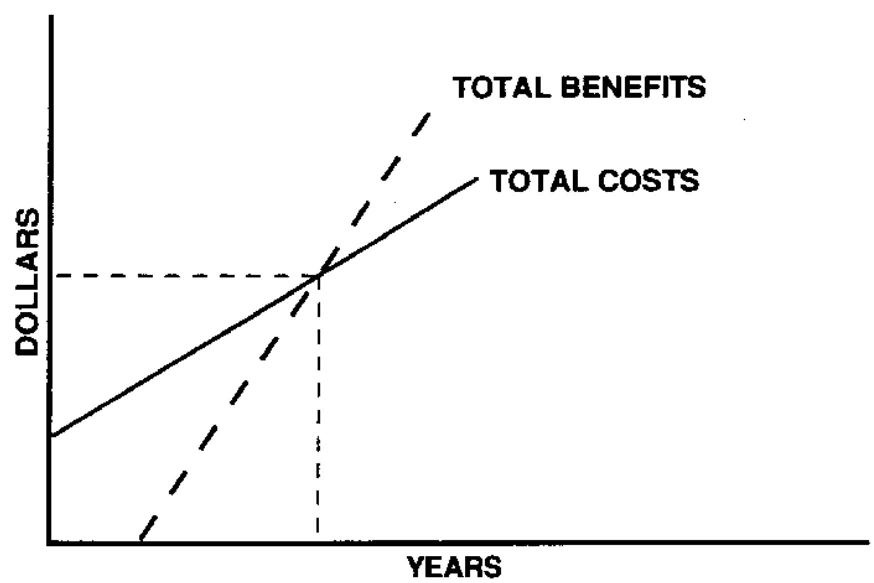

Figure 15-7: Breakeven Point, as Determined by Benefit and Costs Functions

The complexity that must be addressed is that these streams of benefits and costs must all be converted to a single point in time (i.e., present value), in order to make a valid comparison. Such a comparison is usually done by converting all benefits and costs to a present value, as of a specific date.

Interest Rate

A fourth complexity, related to the third, is what interest rate should be used to convert all values to the present. Care should be exercised to ensure that the selected interest rate does not have an unintended (or unknown) impact on the final outcome of the BCA. Conversely, the interest rate should not be selected to produce an intended impact. That is, the discount rate should be objectively selected, not subjectively selected so as to yield the desired result.

Analysis of System Output

Benefits are often measured in terms of reduction in costs. This approach to benefit determination usually assumes the continuation of the current output of goods or services. This assumption can lead to two kinds of problems, first, the continued production of output that is no longer needed or worthwhile and second, the failure to recognize new or future needs of systems users. Both of these assumptions should be carefully examined when carrying out an evaluation of an MPLIS. It is sometimes possible to delete or modify products or processes that exist only because "we have always done it that way." Also, remember that early implementers of MPLIS systems have found that the majority of benefits that have accrued to their new system have been unexpected. Therefore, you can safely assume that several benefits will probably accrue, even though you are unable to identify them when the project is first undertaken.

The bottom line is to keep in mind that BCA, while it is a valuable tool, is not a substitute for the need to make decisions. Many factors, including those outlined above, should be considered when carrying out BCA.

EXAMPLES OF ECONOMIC EVALUATION TECHNIQUES

This section provides a brief overview of several economic evaluations that have been conducted for GIS, LIS, and MPLIS systems. While the emphasis is on benefit/cost analysis, other techniques are included as well. Additional studies cited in the literature are included in the References and Additional Readings section of this chapter.

The list of citations here is not exhaustive. Rather it is illustrative of the kinds of economic evaluations that have been conducted by others and found to be useful. In the discussion here, we will point out strengths and weaknesses of these studies, which is intended to help others who need to conduct an economic evaluation of a land information system or project.

1. "Final Report of the Subcommittee on Benefits and Costs," Wisconsin Land Records Committee, 1987. Available from the Institute for Environmental Studies, University of Wisconsin, 70 Science Hall, Madison, WI 53706. Cost: $ 2.00.

This report provides some guidance as to how to go about conducting a BCA. A brief introduction on BCA is followed by several examples. The examples range from elementary studies to very complex, giving an indication of the scope of analyses for which BCA may be appropriate. A bibliography of articles prepared since 1981 on the application of BCA to LIS and related systems is also included. As is typical, the articles cited generally deal with costs more extensively than benefits.

2. "Land Records: The Cost to the Citizen to Maintain the Present Land Information Base, A Case Study of Wisconsin," prepared by Barbara Larsen, et al., 1978. Published by the Wisconsin Department of Administration, 101 South Webster Street, Madison, WI 53703.

This study is a landmark in the field. While it focuses largely on costs, it was the first, and as yet unreplicated, study that provided an innovative approach to documenting costs of maintaining current, manual systems of land records. It has been widely cited, noting that the costs documented amounted to over $35 per parcel per year, in 1978. Recent updates have projected current costs at over $70 per parcel per year. The study was also effective in focusing attention of policymakers (in the legislature and in state agencies) to LIS issues in general and on economics of LIS in particular.

3. "The Use and Value of a Geodetic Reference System," by Earl F. Epstein and Thomas D. Duchesneau, 1984. Published by the Federal Geodetic Control Committee and available from the National Geodetic Survey Information Branch, 11400 Rockville Pike, Room 26, Rockville, MD 20852, for $5.00.

The Epstein/Duchesneau report is one of the best available examples of classical BCA applied to land information systems. The analysis focuses on four case studies in the application of highway construction, local and regional planning, and private land development.

Several aspects of the report are worthy of note.

a. Value (benefit) determination is examined in terms of the demand for the output of the system, measured in terms of the price consumers are willing to pay for the output.

b. Benefits are measured in terms of costs that government avoids as a result of the operation of the LIS system.

c. The geodetic reference system yielded a large stream of benefits, with a benefit/cost ratio of between 1.7 and 4.5 in the four geographic areas studied.

d. The majority of the benefits were the result of secondary and tertiary uses of spatial information that was based on the geodetic system.

e. The authors argue that benefits of the geodetic system accrue since it provides universal compatibility of information in the LIS that allows many persons other than the initial producers to make use of the data.

The report provides good documentation of the benefits that accrue due to careful planning and development of LIS that use geodetic control networks. These networks provide the basis for coordination and linkage of land information from a variety of files for a variety of functions. These linkages, in turn, permit many users to rely on a common, coordinated data base for a wide variety of uses.

4. "The Development of an Automated Mapping and Land Information System: A Demonstration Project for the Town[ship] of Randall, Kenosha County [Wisconsin]," prepared by the Southeastern Wisconsin Regional Planning Commission, 1985. Available from SEWRPC, P.O. Box 769, 916 N. East Ave., Waukesha, WI 53187-1607 for $10.

This report concentrates on the cost side of the equation. The cost approach is extremely detailed, resulting in a comprehensive look at costs for this pilot study area. Costs are included for all aspects of each function for the mapping and survey control process. Therefore, they appear to be overstated in some cases, since a significant proportion of the work had been completed. This is similar to the situation that exists in many jurisdictions. Therefore, while undue reliance on the specific data in the report is not warranted, the framework and procedures used are noteworthy.

5. "Comparing the Costs: Manual Versus Automated Procedures for Handling Land Records," by D. David Moyer, et, al., 1988, *Proceedings of the American Congress of Surveying and Mapping*, Volume 5, pp. 198-206.

This paper provides cost data on converting four layers of land data to digital form and producing a countywide plan for soil erosion control for Dane County, Wisconsin (see Table 15-1). The Dane County data were extrapolated to produce an estimate of the cost necessary to produce these four automated layers for 54 additional counties in Wisconsin. These other counties actually developed erosion control plans using manual methods and produced hard copy reports, rather that automated systems. Since the State provided nearly $800,000 to the counties to produce the reports in a manual mode, the authors concluded that automated techniques were comparable in cost to manual methods. They also note that by using the automated techniques, Dane County also had available an automated data base that was suitable for many additional uses.

6. "Economic Impacts of LIS Technology upon Sustainable Natural Resource and Agricultural Management," by D. David Moyer and Bernard J. Niemann, Jr., 1991, *Surveying and Land Information Systems*, Vol. 51, No. 1, pp. 17-21.

This paper suggests a method for dealing with the complex analyses that are necessary to evaluate MPLIS systems. Five categories of benefits are suggested and documented: improved efficiency, responsiveness, integration, fairness and equity, and effectiveness. Among the specific analyses are a cost comparison of manual versus scanner data digitization and conventional versus GPS land surveying techniques. The authors conclude that automated LIS systems are necessary to deal effectively with complex government programs being mandated to conserve natural resources.

Table 15-1: Costs to produce automated data layers for soil erosion control planning in Dane County, Wisconsin.

LAYER	COST (1)		
	Per Sq. Mile	Per Twp.	Statewide(2)
Soils(3)	$12.00	$432.00	$480,000
Land Cover (4)	1.50	54.00	60,000
Wetlands (5)	.05	1.80	2,000
PLSS (6)	3.75	135.00	150,000
Production (7)	3.00	108.00	120,000
Total	$20.30	$730.80	$812,000

(1). Based on personnel charges of $12.00 per hour, computing costs of $1.50 per CPU minute and $1.00 per connect hour on VAX 8600 computer.
(2). Extrapolated costs for the approximately 40,000 square miles for which an erosion control plan is required in Wisconsin.
(3). Conversion to digital record, based on scanning technology.
(4). Using LANDSAT Thematic Mapper data.
(5). Data format conversion only (already automated).
(6). PLSS - public land survey section corner information from 1:24,000 USGS Digital Line Graphs (assumes 50% cost share with USGS).
(7). Production costs include analyses, computing, and plotting of seven maps for each township.

SUMMARY

There has been a rapid increase in the implementation and use of land information systems in the past five years. Government agencies and private companies have both contributed to this trend. Based on the systems in place and efforts underway, it appears likely that this trend will continue for the foreseeable future. But in spite of this increasingly acceptable way of handling spatial data, nearly all systems must be justified to decision makers, and generally this justification must be conducted in an economic framework.

Decision makers, whether at the policy or administrative level, must make many choices among competing demands for resources. It is important therefore, that justifications be carried out in a manner that will make the case for MPLIS systems as clearly and convincingly as possible.

Economic evaluations are one approach that has been widely used to justify many publicly funded systems and projects. This chapter suggests that such techniques are generally applicable to LIS evaluation, and provides a number of examples where they have been successfully used. BCA is especially important since it is widely used and generally understood.

However, techniques like BCA may bring additional complexity into the decision making process, since a larger number of relevant impacts may be identified for consideration.

In making economic evaluations of MPLIS systems, new tasks that need to be done, as well as old tasks that are no longer needed, should be documented. Benefits in terms of cost savings and new, improved outputs can often be documented through this process.

While benefit cost analysis is not an easy task, it is a powerful tool that can often provide valuable assistance to decision makers.

Finally, economic evaluation of an MPLIS is an on-going process. Documentation of costs and benefits are just as important for modifying and improving an MPLIS as in supporting initial implementation.

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SECTION THREE

This is a how-to section, covering many of the steps needed in the process of developing a multipurpose land information system.

16 NEEDS ASSESSMENT

William E. Huxhold

Building a Multipurpose Land Information System (MPLIS) is a matter of constructing graphic and nongraphic data bases, developing or obtaining information processing capabilities, installing the appropriate computer hardware and software, and then implementing the organizational, procedural, and staffing changes needed to successfully operate and use the system. These are the essential major tasks to be accomplished, but they cannot be started until all participating agencies know what it is that they expect the system to do for them. Without a clear definition of how each participant in an MPLIS expects to use the system, it will be difficult, if not impossible, to build data bases, select commercial products, and then use the system. Thus, as with most information systems projects, knowing how the system will be used forms the basis for determining what information will be stored in it and what additional technical, organizational, and legal resources will be needed to be able to use that information.

The process for determining these factors is called Needs Assessment. Outside of the conversion of cartographic information on paper maps and manually stored attribute data to digital form, the needs assessment process can be the most time-consuming task in the systems development life cycle of an MPLIS project. Many different types of needs must be considered for the organizations involved. Needs Assessment is a process which determines the answers to many difficult questions, including:

What maps must be produced from the system?
What data must be available from the system?
How are the maps and data to be processed?
Who will update the data?
How will updates be disseminated to the users?
What hardware and software are needed?

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Who needs what types of equipment?
What technical staff is needed to support the system?
Who needs to be trained and what training is needed?
How will the system be funded and supported?

This list is not exhaustive. In deliberating the answers to these questions, other questions will arise related to concerns such as standards, procedural changes, and organizational changes.

This chapter addresses the functional approach to needs assessment, an approach designed to ensure that the goal of the MPLIS project meets the needs of each participating agency and avoids possible failures associated with decisions based on such factors as the "lowest priced" or "most popular" commercial system. The functional approach determines how the use of the system will support the mission of each participating agency. It is not a sophisticated process. It is merely a systematic method for ensuring that the goal of the MPLIS project will meet the needs of each agency. This approach is facilitated through a series of information gathering and documentation tasks. It is hierarchial in nature, where the Functional Needs of each agency determine the Data Needs and how the data are to be Processed to complete those functions. The data and how they are to be processed, in turn, help determine what the Hardware and Software Needs are, which have a large impact on the Staffing and Training needs to support the system. The processing requirements of the system also have a large impact on the changes needed in the operating Procedures for collecting, maintaining, and manipulating the data. Changes in procedures and responsibilities may, in turn, determine changes in the Organizational structure and Institutional arrangements between agencies. What data are collected, who maintains the data, and how dissemination of the data occurs among the agencies may also require certain Legal changes to ensure that the data and procedures are in place when the system is operational. Figure 16-1 depicts this hierarchial process. The subsections of the chapter discuss the needs and resulting changes as illustrated in the figure.

Prior to implementing an MPLIS, each organization has its own way of performing work with resources and procedures that have been in place for a number of years. Maps and land-related data have been stored and maintained manually or in computer files designed for specific purposes. An MPLIS usually changes the method of storage because it is an information system, focusing on a multipurpose data base, rather than an automated mapping system which focuses on computerizing a process.

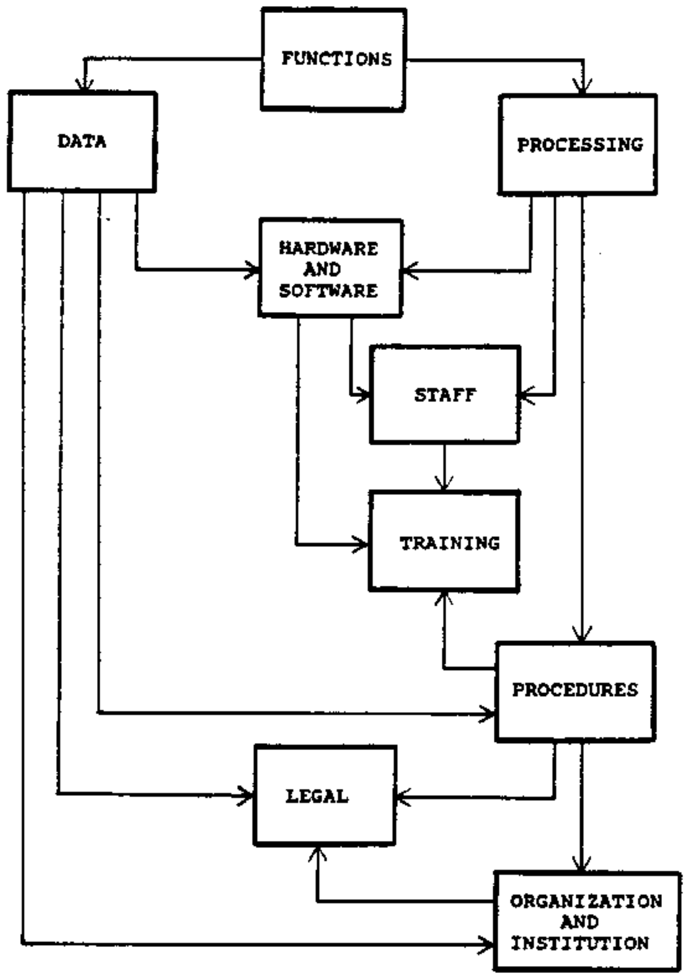

Figure 16-1: Hierarchy of Needs in Developing a Multipurpose Land Information System.

FUNCTIONAL NEEDS

The Functional Needs of an MPLIS determine the parameters for the changes needed in all other categories. This is because the functional responsibilities of each office within each participating agency define how the system will be used. All other needs are then based upon these uses. This functional approach to needs assessment ensures that the system will be an integral part of the operation of each agency rather than a research activity not directly related to their mission.

Functions are those activities which an organization performs to carry out its mission. They are processes involving human activity (e.g., moving, thinking, speaking, decision-making) which require information and which can be enhanced by improving the quality or method for obtaining or processing the information. These activities occur at all levels of the organization, from delivering products or services, to managing resources, to setting policy and long-term strategies. Improving the quality and access to geographic information can improve many of these activities, so the functions that agencies perform must be reviewed in order to identify what data are needed and how they are processed.

All participating agencies of an MPLIS can identify what functions they perform from a number of different internal documents such as organizational charts, mission statements, annual budgets, long-range plans, and other pertinent data. It is important to review all of the activities of the agency because, often, these analyses focus only on maps and related data. Actually many functions rely on information related to locations, not necessarily only on maps. For example, the County Sheriff's office may be required to "Process Subpoenas," delivering legal notices to people ordered to appear in court. While this function may not require a map (other than to find an obscure address), it does require geographic information: the subpoenas may first be distributed to deputies assigned to subareas of the jurisdiction before serving them, or they may be served in a geographic sequence which minimizes the travel time between the addresses of the people being served. In this case, an MPLIS can improve the process of serving subpoenas even if the process does not require a map.

The initial step in defining functional needs of an MPLIS is for each participating agency to identify all of their organizational units (e.g., departments, divisions, bureaus, offices) and to list the functions that require maps or other geographic information. This need not be a tedious or time-consuming task, especially if existing budget or mission documents are readily available, and can be accomplished by one individual in each agency. It is important, however, not to omit any function that may conceivably benefit from an MPLIS (such as "Process Subpoenas"). Later, after implementation, it may be simple to enhance the system to benefit that function if the appropriate standards and resources are established early in the project. Furthermore, what may seem like a trivial application to the project team, may actually be of high importance to the non-technical end user who may see a tremendous benefit from the application and, thus, provide a much-needed benefit early in the project. (Such can be the case, for example, in the simple process of geocoding address-based records. This application need not require digital property maps that can take years to create. It needs only an adequate geographic base file such as a DIME File or TIGER/Line File. The benefits in using these public domain files can have far-reaching effects in geocoding a number of different attribute files for potential users long before the full capabilities of the system are complete.) Figure 16-2 provides a sample list of functions requiring maps or geographic information by organizational unit within a local government.

Department	Function
Board of Zoning Appeals	Hear and Decide Appeals
Building Inspection	Inspect Buildings Issue Code Violation Notices Review Building Plans Issue Permits
Capital Improvements	Prepare CIP Budget
City Clerk	Issue Licenses Enforce License Regulations Research Current Issues
City Development	Perform Development Research Analyze Trends Upgrade Public Housing Stock Assist Community Groups Manage Public Land Dispose of Surplus Property Review Development Proposals Review/Prepare Zoning Changes
Common Council	Provide Political Leadership Discharge Legal Responsibilities Respond to Citizen Complaints
Election Commission	Maintain Voter Registration Establish Voting Wards
Fire Services	Respond to Fires Respond to Medical Emergencies Plan for Fire Resources
Harbor Commission	Market Port Facilities Acquire Waterside Facilities
Health	Process Vital Records Examine Infants/Children/Others Monitor TB/VD/AIDS/Other Investigate Environmental Problems Inspect Food Establishments Investigate Toxic/Hazardous Mtl.
Mayor's Office	Coordinate Long-Range Planning Handle Citizen Inquiries/Complaints Coordinate Research and Policy

Figure 16-2: Sample List of Local Government Functions Requiring Geographic Information.

Department	Function
Police Services	Respond to Calls for Service Manage Police Resources Organize Block Clubs Analyze Crime Trends Investigate Crimes Investigate Traffic Accidents Patrol Neighborhoods Enforce Traffic Laws Apprehend/Arrest Criminals
Public Works	Issue Permits in Public Way Prepare Special Assessments Prepare Paving Program Construct/Maintain Bridges Plan/Design Sewers & Laterals Investigate Flooding Complaints Prepare/ Maintain Maps Plan/Design Roadways Review/Process Developments Provide Engineering Services Inspect Infrastructure construction Evaluate/Plan Pavements Repair/Replace Public Trees Maintain Boulevards/Parks/Other Dispatch Municipal Vehicles Plow Snow/Salt Ice Collect/Dispose of Solid Waste Sweep Streets and Alleys Maintain Sewers/Drainage Channels Repair/Replace Pavement/Sidewalks Design/Repair Traffic Facilities Design/Repair Street Lights Design/Repair Mun. Communications Install/Maintain Lane Markings Read Water Meters Maintain Water Facilities
Tax Commission	Appraise Properties Prepare Assessments Perform Title Searches Maintain Parcel Maps
Telecommunications	Monitor/Inspect Cable TV Inst.
Treasurer	Bill/Collect Property Taxes

Figure 16-2 (continued): Sample List of Local Government Functions Requiring Geographic Information.

DATA NEEDS

Determining what data are needed for processing in an MPLIS is more than merely listing the data items that potential users say they want to be stored in the computer. Since the cost of converting data to digital form, often referred to as "data conversion," exceeds by far the cost of any other component of the system (between 45 and 80 percent of the total cost of the project), it is important to verify that each data item is, in fact, essential (Huxhold 1991, Antenucci 1991). (What good are elevation contour lines in the system when field surveys are taken each time a construction project is undertaken?) In addition, for each item stored in an MPLIS and kept up-to-date during the continued operation of the system, a cost is incurred for "data maintenance." (For example, if building footprints are needed, there is a cost associated with updating that information as buildings are built, modified, and demolished.) Thus, the determination of the data items needed in an MPLIS must be more than a "wish list" agreed upon by all users. It must involve a systematic study of how valuable each data item is for the functions of each user. The next few sections address the systematic approach for identifying critical data, including the use of a matrix for evaluating collected information. Later, in the needs assessment process, it will be important to determine procedures and data maintenance responsibilities required to keep the information up-to-date after they have been converted to digital form.

GEOGRAPHIC INFORMATION NEEDS INVENTORY

A more systematic and comprehensive method for determining data needs is to take an inventory of the data that are currently being used. These data will most likely be used once they are converted to digital form. This can be accomplished by surveying each functional unit within each participating agency to identify what maps and other geographic data are used in each function the organization performs. This process will not only provide a comprehensive approach to needs assessment (ensuring that all functions of an organization are reviewed), but it also ensures that the data which will eventually reside in the MPLIS will also be used on a continual basis.

The inventory of geographic information needs can be accomplished by the use of a survey document such as the example shown in Figure 16-3. This survey document, sent to each functional unit of each participating agency, should be completed by the person who is responsible for the functions of the unit. It is indexed first by the participating agency and then by the functional unit within that agency (much the same as the index of functions from the example in Figure 16-2), and includes a brief description of the mission of that unit. In many cases, each functional unit may include a number of smaller subunits such as bureaus or divisions or offices-each having separate and distinct functional responsibilities. (Public works departments, for example, are normally subdivided into smaller bureaus or divisions such as sanitation, forestry, street maintenance. Likewise, a public utility may have a large construction division subdivided into responsibilities for different facilities such as distribution systems and plant facilities.) In these cases, it is advantageous to also subdivide the inventory by having each subunit complete its own survey document.

AGENCY: ____________________

FUNCTIONAL UNIT: ____________________

MISSION: ____________________

SUB:UNIT: ____________________

Functions	Maps or Drawings Used	Maps or Drawings Produced	Other Data Used	Source

Current Map or Data Problems:

Future Needs:

Figure 16-3: Sample Geographic Information Needs Inventory Form.

Completion of the survey document listing the Geographic Information Needs Inventory identifies which maps or drawings or other data are important for successful completion of each function in the unit or subunit. Recordation of this information for all participating agencies is a critical step towards the final determination of the content of the data bases required for an MPLIS. It also lays the foundation for the procedures that will be required for operation of the system because it also identifies the flow of the maps, drawings, and data through the agencies (and, eventually, between agencies). Figure 16-4 depicts graphically the process used for permit review.

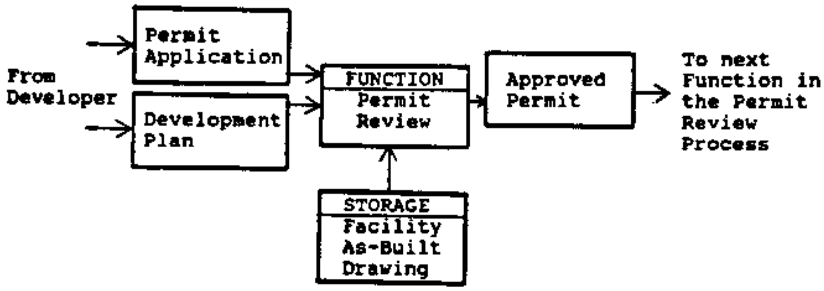

Figure 16-4: The Flow of Geographic Information Through a Function.

The permit review function shown in Figure 16-4 is an example of the geographic information needs inventory because many local governments and utility companies use this function. The function involves the use of many different types of geographic information flowing among many agencies and units within agencies, each agency reviewing a particular aspect of a proposed change in the physical environment of the jurisdiction. In this function, for example, a developer submits a request (permit application form) for a change (development plan) to one unit of an agency for approval. This unit then retrieves (from storage) additional information describing the facilities that are already in place (and where they are) in the form of an "as-built" drawing. Based upon the plan and the existing facilities from the as-built drawing, the review process may result in an approval and transmission of the information to another unit (or another agency) where the change is reviewed with respect to different facilities. The geographic information needs inventory keeps a record of what maps and other data are needed (permit application, development plan, and as-built drawing) to perform the function (permit review), where they come from (the developer), and where the results of the function are sent (the next function in the review process).

A disadvantage of the inventory approach to data needs analysis, however, is that it addresses the current situation only, not necessarily improvements that can be achieved. In some cases, data may be used in a certain function only because other, more accurate or pertinent information is not available due to cost or time constraints. Often, estimates are made or factors ignored, when having the extra data could have improved the effectiveness of the function. Take, for example, a zoning map that does not include parcel boundaries. In many jurisdictions, zoning maps are separate maps with zoning district boundaries identified in relation to the public right-of-way. These maps are maintained by a unit of local government. Since parcel boundary changes may be recorded by a different unit or even a different level of government, ongoing maintenance of parcel boundaries on the zoning map would be too costly, causing duplicative work by two different units of government. When zoning issues arise that affect properties near the boundary of zoning districts, the zoning maps are useless in accurately identifying each affected parcel.

To avoid automating an already inefficient or ineffective process, the geographic information needs inventory must also record information about problems or inefficiencies in the current use of geographic information. Later, in the design of the data bases or processing functions of the system, these problems can be addressed and, possibly, corrected. Another important consideration in completing the geographic information needs inventory is anticipation of changes to the function of the unit in the future. These may have an impact on the data needed to perform the function. These Future Needs may be as extreme as a reorganization of the agency or a new law that is likely to be enacted (such as environmental constraints). The change may be more subtle, such as estimates of increased volume of work (such as a new or growing jurisdiction). It is often advantageous for the MPLIS project team to assist the unit manager in completing the survey document in order to raise issues about problems and future changes.

MAP INVENTORY

One of the results of the geographic information needs inventory is the identification of all maps and drawings used by the participating agencies. This inventory of mapping needs provides the background for the next step in the analysis of data needs: a detailed description of each map and drawing in the inventory. (See Figure 16-5.) Since each map or drawing used in the functions of the participating agencies is a candidate for inclusion in the MPLIS, it is important at this early planning stage to have a detailed description of each map and its features, range of geographic coverage, scale, accuracy, procedures for updating, and users. This inventory will be useful for:

* Determining what features need to be converted to digital form;

* Estimating the amount of work (and potential cost) to convert the data;

* Estimating the potential benefits that can be realized in reducing the time it takes to update, create, and use the data once they have been converted to digital form;

* Determining the amount of redundant map maintenance that can be eliminated by combining the geographic data into one common data base;

* Assisting in the evaluation of hardware needs for storing and processing the data.

Map or Drawing Name: ______________________

Functional Unit Responsible
for Maintenance/Dissemination: ______________________

Geographic Coverage:
Each Map/Drawing Sheet: ______________________
Entire Set or Series: ______________________

Scale: ______________________

Accuracy: ______________________

Source of Base Information: ______________________

Causes for Updates/Changes: ______________________

Frequency and Volume of
Updates and Changes: ______________________

Time Spent in Updating: ______________________

Sources of Updates/Changes: ______________________

Dissemination:	Recipient	Frequency
	______________	________
	______________	________
	______________	________
	______________	________

List of Features Displayed: ______________________

Figure 16-5: Sample Map Inventory Form.

GEOGRAPHIC INFORMATION NEEDS MATRIX

Completion of the geographic information needs inventory and the map inventory surveys provides the MPLIS project team with a vast amount of information about how each participating agency uses geographic information, what maps are currently used, and what problems, inefficiencies, and future changes are anticipated in the use of the maps and data. Indeed, with each agency having many different functional units and subunits, the volume of recorded survey results can be difficult to manage and close to impossible to digest for use in planning the project.

A systematic method for evaluating the results of the surveys is needed in order to apply the appropriate perspective to the remaining steps of the needs assessment. Specifically, some degree of priority must be assigned to the information obtained because it is unlikely that an MPLIS can meet all the needs documented, at least in the initial implementation phase. It is also valuable to differentiate between the common needs of all participants and the unique needs that can be satisfied locally by individual agencies.

One method for summarizing the results of these surveys is to prepare a geographic information needs matrix that displays graphically, the interrelationships and common needs of all relevant functions potentially affected by the MPLIS. The geographic information needs matrix lists all functions surveyed on one axis and all maps and data used on the other axis. (See Figure 16-6.) The code in each cell where rows and columns intersect gives an indication of the importance of the map in that function. If a map is not used at all in the function the cell is left blank. If a map is essential for that function, then the cell is fully shaded. Ancillary uses (ones that may not be important or are only important at certain times) can be shaded some gradient between these two extremes.

The geographic information needs matrix provides a management overview of the extent of common geographic information needs across functions and agencies (represented by the maps having the most cells shaded) and the degree of dependency each functional unit has on geographic information (represented by the functions having the most cells shaded). This can be helpful both in setting priorities for involvement in the MPLIS and for determining the contents of a common digital land base for use by all participating agencies. It is also useful for

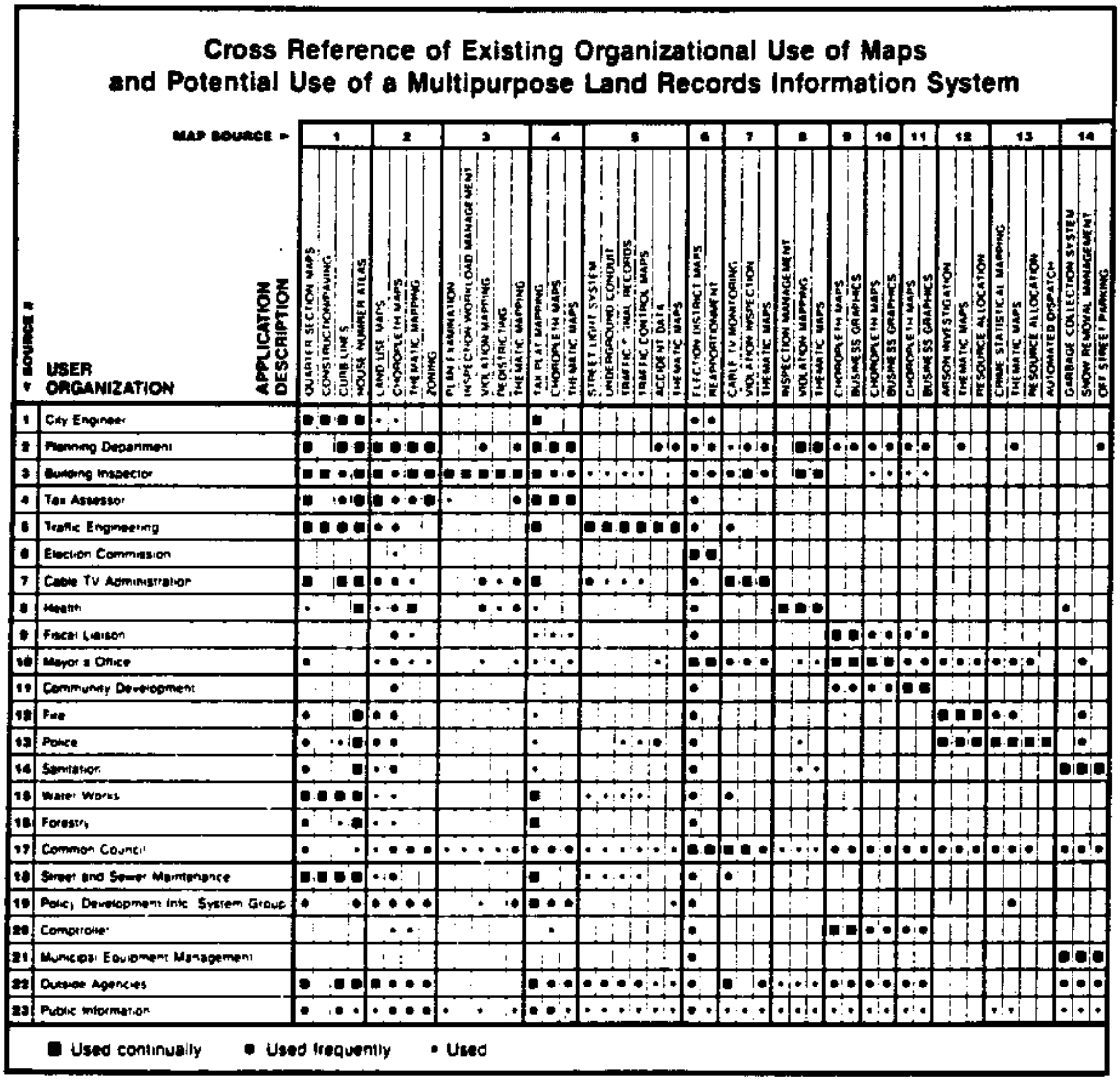

Figure 16-6: An Information Needs Matrix for a Multipurpose Land Information System, cross-referencing land information needs with user organizations. (From: Wisconsin Land Information Newsletter, Vol. 3, No. 2, 1986. Reprinted with permission of: The Land Information and Computer Graphics Facility, University of Wisconsin-Madison.)

determining the proportion of costs that each agency should be assigned when allocating the costs of the entire project to the participating agencies.

THE SHARED LAND BASE

The integrating factor among the participants of an MPLIS is the information contained in the system-the geographic data that are used by all agencies to fulfill the requirements of their missions. This common base of geographic data is usually referred to as a Shared Land Base or a Base Map (See Chapter 12). Participating agencies share much of the common information: street names, waterbody boundaries, building addresses, municipality and county boundaries, and the like. For each agency to independently create and maintain the digital records of this information is inefficient and potentially dangerous, posing a problem to data accuracy and currency. Indeed, the major advantage of an MPLIS is the elimination of redundant map data maintenance because certain features that can be mapped are needed by all agencies. Thus, a common base of data with features updated only by the agency that is responsible for the records can be valuable. It is not necessary for an MPLIS to be a single configuration of hardware and software used by all participants, because functions vary from agency to agency and different technology satisfies different needs.

By reviewing the geographic information needs matrix, it is possible to identify the sources of data for the shared land base. Maps that are used by all agencies (those that have shading in at least one cell for each agency) are the ones that contain features that are potential candidates for a shared land base. By reviewing the features contained on these maps from their descriptions in the map inventory, it is possible to determine what the components of the shared land base should be.

Figure 16-7, for example, lists the components of a shared land base for a typical MPLIS consisting of local governments and public utility companies. It is divided into four classes of features: survey control features, planimetric features, topographic features, and cadastral features. While the systems of each agency may contain additional data that are crucial to the successful use of their system, common data found in the shared land base and used by all participants are most valuable. Chapter 12 gives a detailed description of these shared features, summarized below:

<u>Survey Control Features</u> - In order to ensure that all features are accurately mapped in relation to each other and to the Earth, it is necessary to establish and record certain features that provide common geographic references on a continuous coordinate system for the geographic area contained in an MPLIS. This can be done through the use of <u>Monuments</u> that are physically placed in the earth and whose locations are recorded in the shared land base

(usually by State plane coordinates, Universal Transverse Mercator coordinates, or latitude/longitude). Chapters 3 and 6 contain further details on geodetic frameworks and geographic positions for property corners for an MPLIS.

Planimetric Features - Physical objects that can be seen on the ground (roads, railroads, rivers, shoreline, buildings, and other features) are planimetric features that all participants in an MPLIS project use when recording information about their facilities and other location-related information.

Topographic Features - When all or most of the participants of an MPLIS require information about the terrain in terms of its slope and elevation above sea level (hypsography), then the topography of the jurisdiction must be recorded and maintained in the shared land base. Commonly recorded topographic features include spot elevation values and their locations and contour lines having a vertical elevation interval of from 1 to 5 ft.

Cadastral Features - Cadastral features are geographic features that cannot be seen on the ground (other than when planimetric features are also located where they are recorded such as fencelines located on property lines). In their broadest sense, cadastral features represent the locations of legally defined boundaries (e.g., county and municipality boundaries, subdivisions and lot and block numbers, ownership parcels, and easements).

SURVEY CONTROL FEATURES

MONUMENTS:
- Section Corners
- Quarter Section Corners
- Other Monuments
- Benchmarks
- Survey Control (Bearing & Distance)

PLANIMETRIC FEATURES

ROADS:
- Edge of Travelway
- Centerlines
- Street Name
- Private Roads
- Medians/Boulevards

RAILROADS:
- Railroad Name
- Railroad Right of Way
- Railroad Centerlines

HYDROGRAPHY:
- Wetland Boundaries
- Waterbody Boundaries
- Waterbody Name
- Floodway Boundaries

MISCELLANEOUS:
- Airports
- Bridges
- Building Footprints
- Culverts
- Dams
- Driveways

Figure 16-7: Components of a Shared Land Base.

Fencelines
Parks/Recreation Areas
Piers
Retaining Walls
Trees
Walkways
Wooded Areas

TOPOGRAPHIC FEATURES:
2' Contour Lines
Spot Elevations

CADASTRAL FEATURES
COUNTY:
County Boundaries
County Name
MUNICIPALITY:
Municipal Boundaries
Municipality Name
TOWNSHIP/RANGE:
Township/Range Lines
Township/Range Name
SECTION:
Section Lines
Section Dimensions
Section Number
QUARTER SECTION:
Quarter Section Lines
Quarter Section Dimensions
Quarter Section Number
SUBDIVISION:
Subdivision Boundaries
Subdivision Dimensions
Subdivision Name
CERTIFIED SURVEY MAP:
Certified Survey Map Boundaries
Certified Survey Map Dimensions
Certified Survey Map Name
LANDS:
Land Divisions
Land Division Dimensions
LOT/PARCEL:
Lot Lines
Lot Number
Block Number
Parcel Ownership Lines
Parcel Ownership Dimensions
Parcel Address
Parcel Number
Parcel Owner
EASEMENTS:
Easement Lines
Easement Dimensions
Easement Name/Purpose

Figure 16-7 (continued): Components of a Shared Land Base.

PROCESSING NEEDS

The Processing Needs of an MPLIS define how the data are to be used to fulfill the functional needs of the organization once the system is operational. Often referred to as "Applications," processing needs can be identified by analyzing the functions of the organization that will benefit from the use of the system. (See Figure 16-2.) Associating the applications to be developed for the system with the functional needs of the organization will ensure that the processing capabilities of the system are consistent with the overall mission and responsibilities of the organization.

Defining these applications can be initiated early in the project planning phase and often is accomplished during the analysis of data needs. Such applications require data for processing (inputs), and often produce products (outputs) which are used in the function or by other functions. For example, the permit review function depicted in Figure 16-4 requires three inputs (permit application, development plan, and a facility as-built drawing) and, upon completion of the review function (or process), produces one output (approved permit). This procedure -- receiving inputs, processing the information from those inputs, and producing an output or some other result forms the basic structure around which the processing needs can be identified and documented in order to define the applications that are needed in the system as shown in Figure 16-8.

Figure 16-8: An Application Defines the Processing of Data Needed to Support a Function.

Determining the processing needs of an MPLIS, then, is a matter of investigating each function of the participating agencies and answering the following three questions for each:

1. What data are processed (inputs)?
2. How are the data used (applications)?
3. What is done with the data after they have been processed (outputs)?

APPLICATIONS

Once the functions that will be supported by the MPLIS have been defined (as recorded in Figure 16-2), the applications that will be needed for processing the data contained in the system can be determined and documented. The geographic information needs inventory (Figure 16-3) contains most of the basic information needed to define the application: functions, maps or drawings used and produced, and other data used. All that is needed is a little more structure to the analysis. This structure takes the form of identifying the step-by-step procedures used to complete each function (usually accomplished by interviewing those people involved or by referring to documented standard procedures).

Take, for example, the local government function identified in Figure 16-2 as "Review and Prepare Zoning Changes." In analyzing the processing needs of this function, it is possible to identify all of the steps taken by the functional unit to "Review and Prepare Zoning Changes." A typical set of steps may include:

1. Receive zoning change request.
2. Review existing zoning in the vicinity.
3. Identify current land use for the area and surrounding area.
4. Compare the situation with established legal restrictions and requirements.
5. Identify and notify property owners in the area.
6. Conduct a public hearing on the request.
7. Prepare map and ordinance changes.
8. Obtain the necessary approvals.

Breaking a function down into these smaller steps makes it easier to identify the specific applications that must be developed for the system to assist in the processing of data in the function. For example, the second step, "Review existing zoning in the vicinity," requires a process whereby the system can be requested to display a map of existing zoning within a certain geographic area. Thus, the need to process data (review existing data) defines the application: "Display zoning map information for an area defined by the user."

In order to develop this application, however, the system must know two things:

* What is the geographic area?
* What information, besides zoning, should be displayed?

The answer to the first question defines the data inputs needed for the application, and the answer to the second defines the output product. Hence, once the application has been identified, it is necessary to identify the inputs that need to be processed and the outputs necessary for the function.

DATA INPUTS

The data that provide input to an application come from two sources: data that are input externally by the user and data that are stored within the data base. There is no other source of data for the computer (other than, perhaps, data stored within the program logic itself such as a rate, measurement, or some other parameter that seldom changes). Thus, the applications developed to satisfy the processing needs of an MPLIS must specify what data are needed as input by the user and what data are needed from the data base.

In our zoning example, the data input required from the user is an identification of the geographic area that must be displayed. This can be accomplished in one of two ways: either the user defines the parcel of land (e.g., by an address, a parcel identifier) and the application determines how large an area to display (through a parameter stored in the program logic), or the user defines the area to be displayed (by first identifying the parcel and then defining the size of the surrounding area to display).

DATA OUTPUTS

Data can be produced as output from an application in a number of different forms:

* hardcopy maps
* hardcopy tabular reports
* screen map display
* screen tabular display
* digital file to be used in another application
* image on microfilm, video disk, or other medium
* data base (when existing data are updated)

It is necessary to define the specific output medium required for each application so that the appropriate design methods for that medium can be applied. The most important consideration, however, in defining the data outputs from an application is what data must be produced.

Our zoning example requires a map of zoning information to be displayed (presumably on a screen map display and probably also on a hardcopy map). It is also obvious, however, that more than just "zoning" data are required on the output. What is not obvious is just what other data need to be displayed: parcel boundaries, parcel dimensions, street names, owner names, addresses, water main sizes? An explicit definition of each data item needed as output as well as the medium upon which they are to be output is needed.

DOCUMENTING THE PROCESSING NEEDS

In order to keep a record of all the processing needs desired for an MPLIS it is helpful to maintain a standard format that identifies the specifications of the applications. This can be accomplished by preparing a standard application definition form that contains:

* Data input requirements
* Processing requirements
* Output products

In addition, the form should also identify the function in which it will be used when the system is operational. Figure 16-9 shows an example of an application definition form.

APPLICATION: Display zoning map information for an area defined by the user.

FUNCTIONS USING THE APPLICATION: Review and Prepare Zoning Changes

DESCRIPTION OF APPLICATION:
This application uses zoning and related parcel-based data from the data base to display existing information related to zoning for a specific area that is defined by the user. The application must be available interactively at a work station when the user invokes a request and identifies the subject land parcel. The application will define a search area based upon the search distance defined and input by the user and will display all required data for the area within the specified distance from the outer boundary of the subject parcel.

DATA INPUTS:
User Defined:
Parcel identifier
Search distance

Data Base:
Zoning boundaries
Zoning dimensions
Zoning codes
Parcel boundaries
Parcel dimensions
Parcel numbers
Street names
Addresses

PRODUCTS OUTPUT:
1. Zoning map screen display with subject parcel highlighted, search area boundaries, search distance, all zoning data, parcel data, street names, and addresses.

2. Hardcopy map of the above.

Figure 16-9: Sample Applications Definition Form.

Once all of the applications for the system have been defined in this manner, the planning process can begin to analyze the scope of the MPLIS in order to structure the approach needed to schedule the remaining phases of the project. Large, multi-agency projects may define hundreds of applications during the needs assessment because of the diverse functions represented by the participating agencies. Even single-agency projects with diverse functional units can have a large number of applications defined after the analysis of processing needs. At this stage of the planning process, now that the data and the processing needs are documented, it is necessary to review these needs and group them into phases. In this way an orderly schedule can be developed for assigning resources and responsibilities, establishing milestones for managing the implementation process, and allocating funds throughout the multiyear implementation process. Since all applications cannot be developed and implemented at the same time, it will be necessary to assign some priority or rank to each application so that those which are most important can be implemented first. This will assist in establishing a plan for data base conversion, hardware and software acquisition, and other activities.

The setting of priorities or ranks can be a difficult task because of the number of different agencies and functional units involved in the project. With many different personalities, funding sources and amounts, political and organizational environments, and other related influences affecting the needs assessment process, effective project leadership and communication are important in setting application priorities. One way to avoid controversies and gain consensus during this step is to obtain agreement beforehand on the criteria that should be used to measure the importance or priority of each application. Below is a recommended grouping of priorities into three categories:

<u>High Priority</u> applications are extremely important and may be defined as those that:

* have the greatest impact among all participants;
* are most often used in the day-to-day operations of the agencies;
* are the most labor-intensive when done manually; or
* are currently experiencing the most problems which have a direct effect on a major function.

Moderate Priority applications are important, but do not have the urgency that warrants a high priority. They may be characterized by conditions that:

* provide general capabilities that can apply to more than one type of data or situation;
* affect standard functions that do not have a high volume of use; or
* affect functions that do not have a major impact on the daily operations of the agencies.

Low Priority applications have the lowest impact on the success of the system because they:

* provide capabilities that affect only one or a small number of functional units;
* provide a capability that cannot be achieved until another application is implemented;
* provide a capability that is not needed immediately, but will be at some future time; or
* enhance a function by creating a new capability that is not currently performed.

The establishment of application priorities does not have to result in a rigid schedule that governs exactly when each application will be implemented. The analysis, installation, and creation process for the base map consume a large amount of time. Conditions affecting certain applications are likely to change during the course of the project's development. The above priorities do, however, provide guidance and direction for the establishment of hardware, software, and data base requirements. The information is helpful when scheduling resources and in providing estimates for costs and benefits over a multiyear timeframe.

HARDWARE AND SOFTWARE NEEDS

Now that it is known which functions of each agency will be using the MPLIS, what the content of the data base will be, and what applications are needed to support the processing of the data for these functions, it is possible to begin to specify the hardware and software needs of the system. As discussed, the functions (Figure 16-2) define where the hardware components will be needed; the data base content (Figures 16-3 and 16-5) defines the size, source, and update volumes of the data storage components; and the application definitions (Figure 16-9) form the basis of the software capabilities required of the system.

In all information systems development projects, it is the applications that define the software capabilities that are needed and it is the software that defines which types and mixture of hardware components must be installed. The MPLIS, while complicated by the spatial nature of the data and the breadth of involvement by many participants, is no different. There are more than 60 vendors of GIS hardware and software on the market today. These range from single-purpose, microcomputer-based technology to large work station networks and mainframe-based systems, making it impossible to select the most appropriate system without first analyzing each in terms of the important applications for the particular MPLIS being planned.

SOFTWARE

In general, GIS software capabilities can be grouped into three functional classifications:

* automated mapping functions
* data management functions
* spatial analysis functions

Each application should be reviewed with respect to the users' need for these three types of functions.

Automated mapping functions - These functions manipulate the cartographic records of the MPLIS for the purpose of updating, creating, extracting, and producing high-quality maps and drawings. Their focus is on the specific mapping process itself. Thus, applications which place a high importance on mapping and drafting operations may require such functions as:

* coordinate transformation
* map scale conversion
* coordinate geometry (COGO)
* edge-matching
* windowing
* curve fitting
* area calculation
* line length calculation

* text placement
* snapping
* copy parallel
* precision entry
* rubber sheeting

Data management functions - These functions manipulate the nongraphics data stored in the MPLIS data bases. They create and update data, retrieve and manipulate selected records, and produce standard and ad hoc reports. Applications with a heavy dependance on attribute data may require such functions as:

* ad hoc inquiry
* ad hoc report generation
* summary
* security
* Boolean logic
* standard data entry forms

Spatial analysis functions - These functions use both cartographic data and attribute data for processing in a spatial context, often with topological relationships. These functions produce results of analyses in a statistical nature and often create new maps or new data bases. Applications requiring spatial analysis capabilities may require such functions as:

* proximal analysis
* network analysis
* polygon overlay
* point-in-polygon
* choroplethic mapping
* buffering
* spatial aggregation

In addition to the abovementioned software functions, there are other software functions that may be required. These are of a more general nature or they may address a unique situation, such as a computing environment that is already in place and planned as a resource in the new system. Some considerations include the following:

Communications software - If data files must be transferred among work stations or if different software is needed by different users, then it may be advantageous to use communications software in a network environment.

Menu design - Many sophisticated commercial systems offer a facility whereby the menus used to supply commands to the system (either on a tablet, keyboard, or screen display) can be tailored for a specific application at a specific user work station. Programming these menus allows the user to select certain options to perform system functions so that individual commands do not have to be used.

Symbology creation - In the design of specific map outputs, it will be necessary to establish standard symbols, text fonts, and line symbology (such as those used in portraying water main valves, land use symbols, and railroad lines). While most systems provide a range of "built in" symbols for many features, they also provide a capability to design specific symbols and fonts that may be desired for a unique situation or installation.

Interfaces with existing packages - If a specific data base management system is currently being used and contains data for the system, or if the system must interface directly with an installed computer-assisted mass appraisal system, computer-aided dispatch system, or other special-purpose system, then these requirements must be identified prior to the selection of the software for the MPLIS.

Other customized programming - In addition to the above software needs that may be unique to an installation, other special programming needs that may be required include: standard map designs, special macro-level programs, and file archiving programs.

HARDWARE

By waiting until after the data, processing, and software needs of an MPLIS are determined, defining what hardware components are needed can be a fairly uncomplicated task. The easiest approach is to analyze hardware needs in a backwards fashion: determine what devices will be needed by the users whose applications are being implemented in accordance with the plan. By looking at the input and output needs of the applications for each user (see Figure 16-9), the specific hardware requirements for those users can be identified:

* Work stations
* Plotters
* Digitizers
* Printers
* Scanners
* Alphanumeric terminals

A brief discussion of these input/output devices will shed some light on the various criteria that should be applied to their selection:

Work station - There are two general options to consider when evaluating the need for the computer work stations that will be used in each application: a terminal connected to a centralized computer (such as a microcomputer, minicomputer, or a mainframe) which may also have additional terminals connected to it, or an intelligent work station (which is a computer) connected to other intelligent work stations and computers on a communications network. The criteria used to determine which configuration is most appropriate relate to software functionality, system hardware use, and data file availability.

In a centralized computer system with one or many terminals connected to a single computer, all software and data files reside on the computer and all terminals use the same software and data files. This configuration also usually requires plotters to be connected directly to the computer (although some lower quality hardcopy output devices can be connected directly to the terminal). Central software produces the plots. The computer may also be connected to another computer so that data files (or even update and inquiry transactions) can be transferred, but the speed of these communications can be limited.

The network configuration allows a much more versatile use of software, hardware, and data files. Each computer (micro, mini, or mainframe) connected to the network can operate independently of the other computers (much the same as with the centralized configuration) with its own software, hardware devices, and data files. However, each computer can also have access to the data files, software, and hardware devices of the other computers on the network. This can improve system response time because the files are not transferred between computers, and access is provided directly. Outputs can be directed to any plotter on the network, regardless of the computer to which it is connected. Software can be unique to each computer on the network, allowing a single data file to be used by different software in different functional units.

Determining the user's work station needs depends upon whether a versatile computing environment is necessary. Where all users require the same software functionality, the same data bases, and users are located close together without being physically dispersed (so that they have easy access to a plotter and other centrally located devices), then a centralized computer system may be appropriate. This configuration is often less expensive than a network-based system and is less complex, requiring less technical expertise and support on an ongoing basis. If, however, users are physically separated at different sites, have a variety of diverse software needs (e.g., automated mapping, data base query and manipulation, spatial analysis), anticipate a wide variety of different data bases -- each maintained separately by different functional units -- , then a network-based system may be more appropriate.

It is also important to consider future needs in deciding upon the hardware configuration needed, especially those applications that were given a low priority. The system may expand once the initial applications are implemented.

Plotters - Again, the applications planned for implementation on the system should determine the type and number of plotting devices needed. Since plotters are high-cost components of a system, it is important to balance the cost associated with the various features of different plotters with the specific needs of each application. Variable features of different plotters include size, quality, and speed of output as well as color. Applications that require high-quality output production may require a pen plotter unless the users responsible for the output are satisfied with the quality of an electrostatic plotter. (A sample output from each type of plotter is usually necessary for such determination.) Consideration for the degree of output quality, however, must be balanced with the speed of output (pen plotters are slower) as well as ongoing maintenance (pen plotters require constant attention and maintenance of pens, ink, and other components). Applications that require a high volume of output should consider the use of an electrostatic plotter since pen plotters can be as much as 10 to 100 times slower. For applications with high volume and high quality output requirements, it may be beneficial to consider a computer output microfilm (COM) device that produces the final plot directly onto film for later processing onto paper medium. Color may be important in some applications (such as highlighting certain features for edit checking or for producing presentation-style maps for communicating the results of analyses). However, color plotters are more expensive and also require more attention and maintenance. Applications that do not require large plots or high-quality output, but do need some hardcopy product, may be able to make use of low-cost laser printers that can be connected directly to a work station for easy access.

Digitizers - Large digitizing tables are needed only in certain situations and applications. During the initial process of creating the data base, it may be necessary to use such tables if existing map products are used. Later, after the data base is completed, these large tables will not be critical since updates can be made directly at the work station screen with a smaller, less expensive editing digitizing tablet.

Scanners - It may be possible to avoid the time-consuming process of digitizing map information by using an optical scanner to read the entire map sheet and convert it to a "raster" image in digital form. This raster image is merely a series of minute dots stored in a huge matrix covering the entire area of the map sheet. After the map is scanned, these dots are coded either black or white, depending upon the presence of ink on the map. Thus, the raster image of the map is actually a digital picture of the map. It then must be converted to vector form (so that a line is defined instead of a series of dots, for example) by executing specialized software. Later, the features must be edited so that they are placed on their appropriate layers and text must be edited for placement in the data base if desired. This process of editing can be very time-consuming and may take more time than digitizing, depending upon the contents of the map. Generally, when scanners are used, they are used only during the initial base map creation process. Updates to the digital maps are most often done on digitizing boards.

Printers - When tabular reports are needed in hardcopy form, it may be necessary to install a printer at those work stations that need the output, although some plotters may be used for low volume report generation. If large volumes of tabular listings are needed, however, more expensive high-speed printers should be considered and shared at some central location.

Alphanumeric Terminals - Since graphic work stations can be expensive, it is often desirable to install lower-priced alphanumeric terminals where graphic output is not needed. This may be possible in the central support location where programming and other system support functions are performed. These alphanumeric terminals are much less expensive than graphics work stations and provide a better cost alternative when graphic displays are not needed.

STAFFING NEEDS

The human resources needed to first implement and later support the operation of an MPLIS are a critical component of the project and eventually become the largest ongoing cost of the system. Successful systems in the past have relied on an adequate number of dedicated and trained staff members. Their success has been largely attributed to the longevity of the project team itself. As with most organizations, then, careful selection, assignment, and management of the people responsible for the system should be an important activity in the development of the system.

While it is important to assign staff full time to the project at its onset, the number of positions and their responsibilities will vary as the project develops from the needs assessment and justification stages through design and implementation, and finally, to full operation. This development cycle will likely consume years, but it is important from a budget and project management standpoint, to plan and schedule the human resources needed at each stage. At the very least, from a cost standpoint, the staff requirements must be estimated and planned during the needs assessment phase in order to provide a realistic cost estimate for the decision-makers in determining the net value of the system to the organization.

The roles that project staff members must assume during the life of the system are described in detail in Chapter 8 and summarized below.

Leader/Manager - The project manager is the leader of the effort to implement the system. In some cases, where funding and authority for the system have not been obtained, the leader of the effort will most likely be an elected official, a department head, or other key person within an organization. In this role, the leader must educate the people who will be involved in the decision-making process and sell the vision of what the system will do for those who will be users once the system is implemented. Later, after funding and approvals are obtained, the manager might be a different person than the leader and will focus more on the project itself: motivating the project staff members and providing management and administrative oversight once the system becomes operational.

Analyst - The analyst is the one who translates what the users of the system need into technical specifications for the functional operations of the hardware and software.

System Administrator - The system administrator is the chief technical professional who ensures that the hardware and software are functioning properly on a day-to-day basis and that new hardware and software are installed properly.

Database Administrator - The database administrator is responsible for the standards, documentation, and technical design of all data bases used in the system. This position works closely with the analyst, programmer, and system administrator to ensure that the physical design of the data bases is appropriate for the specific hardware and software configuration of the system, and that the logical design of the data bases conforms to established standards and documentation requirements.

Programmer - The programmer translates the specifications identified by the analyst for specific user applications into the appropriate commands for the user to invoke when operating the system.

Processor - Often MPLIS users will have a position which combines many of the skills of the analyst and programmer into one that can design many applications that are specific to individual user needs and do not require complex technical knowledge or new data bases. The processor is the "super user" who can implement new applications such as menus, macro language programs, and simple reports or displays.

Digitizer - The digitizer is the person who converts maps to digital form during the base map creation process and who may later become involved in ongoing map features maintenance after conversion.

Other roles - There can be other roles that are needed for specific installations, depending upon the applications to be implemented: Cartographers may be needed to design and produce high-quality map products; Drafters may be required for designing highly technical engineering drawings and construction plans; or photo interpretation specialists may be needed for compiling and integrating cartographic data from aerial photography onto map manuscripts for digitizing.

The specific mixture and number of staff personnel required to fill these roles varies, depending upon the complexity of the system and the stage of the project. For example, a centralized system without the complex network communications software will not require a system administrator with strong network expertise. If the system is relatively small, it may be that a system administrator or database administrator position is not needed at all. These responsibilities could be shared between manager, analyst, and programmer. Similarly, during the needs assessment phase of the project, the programmer and system administrator roles are not necessary, but the position may be needed when the system is actually installed. Figure 16-10 gives an indication of the types of roles ("resources") needed at the various stages of project development. Less technical resources are needed during the study phases, more during the operational phases. The size of the staff may vary depending on the four different system configurations. A single position may be sufficient for a single microcomputer-based system, whereas a large multi-user, network-based system might require seven positions in addition to end-users, contractors, and user groups and steering committees.

TRAINING NEEDS

Once the staffing needs of the project have been determined and the hardware and software needs defined, it is possible to prepare a general plan for the training requirement of the staff involved in the project. There are at least five times during the development of an MPLIS project when training is important:

* Prior to the study and analysis of needs, when an introduction to the technology should be presented to potential users, and project management techniques should be presented to project staff members.

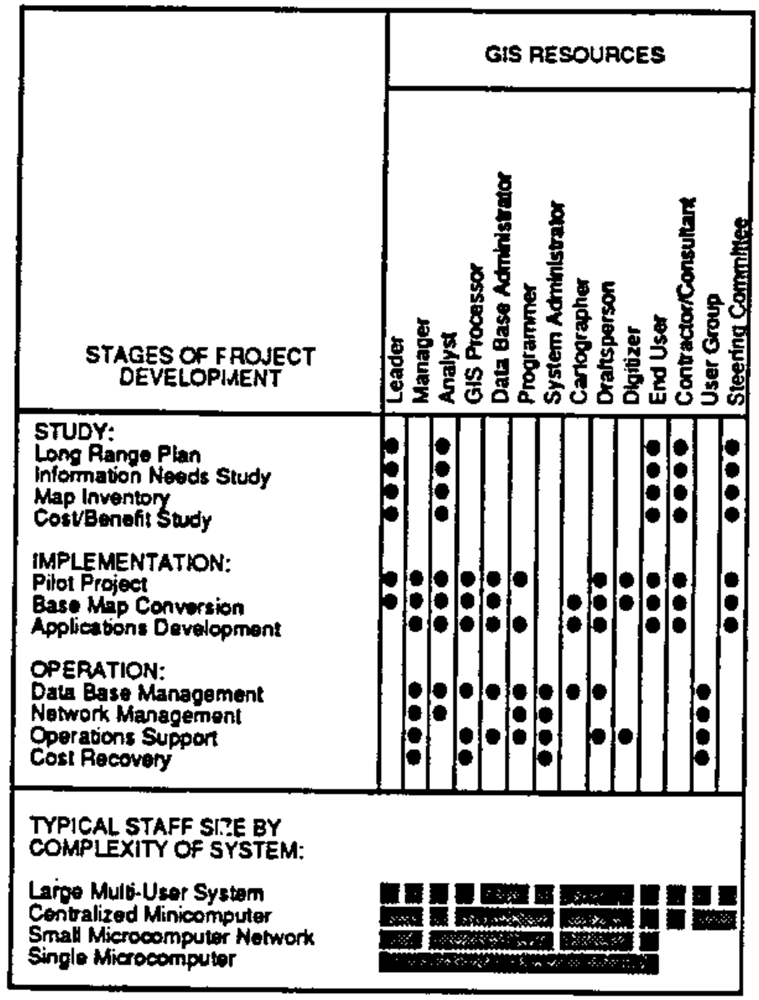

Figure 16-10: Resource "roles" needed for the various stages of MPLIS project development and typical staff sizes for different system configurations. (From: An Introduction to Urban Geographic Information Systems, William E. Huxhold, 1991. Reprinted with permission of Oxford University Press, NY)

* During the study stage, in preparation for the selection of hardware and software, when mapping concepts, data base management concepts, and networking concepts should be introduced.

* During the implementation of the system after a vendor has been selected, but prior to the creation of the data bases and development of applications. This training involves the specific use of the vendor's hardware and software and is usually provided by the vendor.

* After development is complete, but prior to full operation of the system when training on the new procedures and training on computer operations management are required.

* Ongoing over the life of the system after it has become fully operational as new users are added, new products are installed, and new applications are developed.

Exactly which training courses are needed, who receives the training and what sources of training are best depends on what resources are assigned to the project, who the vendors of the hardware and software are, and what previous training and experience the staff has received. Because different people will be involved in the project at different times (see Figure 16-10), and because training can be expensive and time-consuming, it is best to plan for these needs early in the project prior to the completion of the cost/benefit study and implementation plan. Chapter 14 provides a detailed training program for these five stages of the project.

PROCEDURAL NEEDS

It is inevitable that the implementation of an MPLIS will cause changes in the way work is completed and how information flows throughout an organization. While most of these changes will reduce the amount of time and effort spent in completing the tasks of the functional units, there will also be some additional tasks that must be accomplished in order to utilize the new capabilities of the system. After the data needs and processing needs have been determined and the applications developed and vendor training provided, it is now possible to identify and document the procedures that will be needed to use the system on an ongoing basis.

The needs assessment process has identified two activities where one can determine the procedures that must be changed or implemented to successfully use the system on an ongoing basis: the establishment of the shared land base, which identifies the common data needs of all participating functions, and the definition of applications, which defines the computerized processing needs of all users. By analyzing the results of both activities it should be possible to develop written documentation on the procedures necessary to ensure continued efficient use of the system. Chapter 20 discusses these procedures.

ORGANIZATIONAL CHANGES

An MPLIS can have a profound impact on the organizational structure of an agency. While most institutions have been organized into specialized functional units that concentrate on their own specific mission, the implementation of an MPLIS requires these separate functional units to cooperate among themselves in ways that were not required in the past. The fact that valuable information is now stored in a computer system for use by many different functional units (instead of being stored in the physical files and drawers of each separate unit), creates a new organizational atmosphere and philosophy that can affect both the structure of the organization as well as the responsibilities of each unit in the organization.

The most obvious of the issues affecting organizational structure and responsibilities is where to place the responsibility for the system. Throughout the process of assessing needs, implementing the system, and, finally, operating the system on a daily basis, the question of "who's responsible?" must be clearly defined in order to prevent costly delays associated with correcting problems as they are experienced. Successful MPLIS projects have assigned this responsibility to an existing functional unit that has a comprehensive view of the organization: the data processing department, the department of administration, or other similar internal service-based unit. While the leadership and need for an MPLIS may be strongest within a specialized function (planning, engineering, transportation, property records, natural resources, etc.), it is important to consider the organizational placement of responsibility on a long-term basis, organization-wide, because individual influence on the design for a specific (and, usually, urgent) function can cause problems later on that could severely limit the comprehensive use of the system.

For a more comprehensive discussion of the impact of an MPLIS on the organizations using the system, refer to Chapter 8.

INSTITUTIONAL NEEDS

Many MPLIS projects involve more than one organizational entity: municipal governments, county governments, other local and regional agencies, utility companies, special-purpose quasi-public agencies, academic institutions, and commercial organizations. Most agencies of this nature have common interests in land-related information. By working together as a group, the taxpayers, the ratepayers, and stock holders can all benefit from the economies of a joint effort. These joint efforts are usually referred to as "consortia" and almost universally are established because of common needs and cost-sharing. A consortium may be beneficial when the cost of an MPLIS may be too large for any one organization, when the common base map information is collected by more than one agency in a geographic area, and when a cooperative environment for public/private partnerships is in place. A consortium can usually generate enough resources and motivate enough people to ensure a successful MPLIS project implementation and operation.

There are two major issues (other than those mentioned earlier that are internal to each organization) that must be addressed when a consortium effort for an MPLIS is considered: how to share the cost and where to assign responsibilities. The options and their consequences for both issues are discussed in Chapter 8.

LEGAL NEEDS

It may be necessary to obtain some legal or legislative assistance to simplify the implementation of an MPLIS in a particular jurisdiction. The formation of a consortium of different organizational entities to share the cost of a system will require a formal contract and, possibly, enabling legislation by governmental bodies. Some jurisdictions have been handicapped in the development of data bases because of strict state open records laws which prevent them from recovering the cost of development through the sale of data. In addition, these open records laws may prevent an MPLIS project from including the proprietary data of utility companies and other nonpublic users in the shared land base. The project team must investigate current legislation to determine if there are restrictions of this nature and take the actions necessary to obtain exemptions if this is the case. (This was done recently in Oregon to allow the Metropolitan Service District of Portland to charge a fair market value for its data base in order to recover the cost of development.)

New legislation should also be considered to assist local governments to generate new revenues to pay for the cost of a system. In Wisconsin, for example, state laws were changed to allow county governments to increase the recording fee for all property transfers and other legal claims to property to help pay for systems.

The technical development of an MPLIS can also be aided through the legislative process. Chapter 10, for example, described the need for unique parcel identifiers in an MPLIS for relating mapped parcels to nongraphic attributes in data bases. If a jurisdiction is not currently using parcel numbers that are unique across the entire geographic area covered by the system, then local or state laws may be needed to change the parcel numbering system to allow for uniqueness. Further, it may be helpful to amend local legislation to require these unique parcel identifiers on all legal documents pertaining to land so that additional information can be linked to the parcel map. Other legal or legislative assistance that may be useful in assisting the technical development of an MPLIS include:

* requiring all computerized data address files to adhere to a strict address standardization schema.

* requiring all new subdivision plans or legal descriptions of property to contain state plane coordinates.

SUMMARY

This chapter describes the activities required to analyze the needs of an organization or consortium of organizations in order to successfully implement and use an MPLIS. While its primary focus is on the data and the processing of the data in the organization, it also stresses the importance of a functional approach to the assessment of needs: first defining the mission and functions of each unit within the organization or organizations, and then analyzing the data needs and processing needs within those functions. This emphasis on functions and missions is critical for two reasons: first, it assures a comprehensive analysis of needs; and, second, it assures that the system will be a strategic resource to the organization or organizations rather than some research activity that is vulnerable to budget cuts.

Thus, the needs assessment process begins with the identification of functions that can benefit from land information systems (LIS) technology and proceeds to define the data that are needed in those functions and how the data are processed to successfully perform the functions. This information then forms the basis upon which the applications of LIS technology for the particular jurisdiction are defined. It was not until these applications are defined that the analysis of hardware and software is conducted. Indeed, the most objective and comprehensive method for selecting a vendor of LIS technology is to first define the applications that are needed and then find the system that best meets those needs. To do it any other way is an invitation to cost overruns, delayed implementation, and unhappy users. Once the applications, hardware, and software of the system are known, then the needs for staff, training, and procedures for implementing and operating the system can be easily identified. A brief discussion of the organizational, institutional, and legal changes needed to assist in the implementation of the system completes the needs assessment process.

From reading this chapter, it should be evident that planning for an MPLIS is not a simple process. There are no standard checklists. There are no vendors who can tell you what you need and sell it to you. Each jurisdiction is different, with different priorities and resources. Therefore, each jurisdiction must conduct its own needs assessment, ensuring that the resulting system will best meet its own needs.

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17 INSTITUTIONAL ARRANGEMENTS AND ECONOMIC IMPACTS

D. David Moyer
Bernard J. Niemann, Jr.

INTRODUCTION

Land information systems (LIS), including those used by local government for a variety of applications, are proliferating rapidly. At the same time, the benefits and results produced by LIS are occurring at an unknown rate. Some would say at a rate somewhat less than what many developers and users had expected. Others would assert that benefits are occurring as a result of the adoption of GIS and GPS other information technologies, but are being limited by institutional factors. (For an in-depth discussion about how to assess benefits and costs of MPLIS, see Chapter 15 by D. D. Moyer).

We suggest that one of the major reasons for these less-than-expected benefits is our failure to understand and adequately attend to the institutional and organizational aspects of multipurpose LISs (MPLIS). The general tendency is to concentrate on the hardware, software, referencing systems, and data conversion and development portions of MPLIS, and to neglect the people, organizations, institutions, and political context that are equally important parts (possibly more important parts) of the system.

In this chapter we identify and discuss a number of MPLIS institutional and organizational issues, and explore how various government agencies are going about the process of arranging to implement MPLIS technology. We also look at the economic impacts of these institutional arrangements. These impacts are important in themselves, and well documented techniques have been proven for measuring them (Chapter 15). Equally important, for the discussions here, is the increased understanding regarding

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institutional and organizational issues that economic analysis can provide. Economics of MPLIS are central to understanding current systems for handling geographic data, for developing new systems and incorporating them into operating agencies, for "selling" MPLIS to policy makers and upper-level managers, and for the critically important task of moving from traditional information systems to MPLIS in an organization.

IDENTIFYING INSTITUTIONAL ISSUES

Perhaps one reason for the lack of adequate attention to institutional issues is the lack of a clear, simple definition of the term 'institutions,' despite the work of many competent researchers and commentators who have addressed the subject. In this chapter, we use 'institutions' to refer to organizations, agencies, and private establishments and the associated political context that are considered part of an MPLIS. Institutions also include the laws, rules, customs, and practices by which the various spatial data handling activities are carried out in an organization (Wellar, 1993).

Wellar suggests that, in many cases, it is not possible to clearly separate institutional issues from other factors. For example, he argues that institutional issues such as privacy, confidentiality, access to data, and standards are also organizational issues as well. Similarly, the distinction between institutional and organizational issues in this chapter is often blurred.

Issues that we include as institutional for purposes of this discussion cover:

- identification of participants
- multi-agency (multi-participant) agreements
- management structure
- system structure (centralized or network)
- data custodians
- system monitoring
- system maintenance (who, with what frequency)
- resistance to change
- autonomy of agencies
- management support (top level)
- political support
- standards (hardware, software, data, etc.)
- geo-referencing framework requirements
- data sharing (do data exist?, at what scale?, in what format?, on what medium?, etc.)
- data collection (what items?, what resolution?, what accuracy?, what currency?, etc.)

- data quality
- funding options
- shared costs
- cost recovery
- end-user pricing
- legal issues (privacy, confidentiality, data access, liability, etc.)
- public opinion
- public confidence and
- implementation strategies (i.e., evolution of system over time).

Even this is not an exhaustive list of institutional issues; rather, it is indicative of the kinds of issues that fall into the institutional arena. If nothing else, it attests to the complexity of institutional aspects of MPLIS. As 'multipurpose' becomes an increasingly important aspect of LIS, the complexity of institutional issues involved increases as well. A sampling is discussed in the remainder of this chapter.

The sharing of a common data base is often a key factor that brings agencies, divisions, etc., together to support an MPLIS. (See, for example, the discussion by Moyer (1990)). One example of an MPLIS model is shown in Figure 17.1. This model will be discussed in more detail later, but what is conceptually important is that the potential and inherent power of MPLIS technology is conveyed by the graphic portion of the diagram -- the ability to query, manipulate, and integrate various layers of information. The constraints on this potential of the technology are represented by the variety of institutions that by convention, by law or by choice are the day-to-day custodians of these various layers. To fully exploit the potential of MPLIS requires cooperation from all these institutions. Suffice it to say that multipurpose systems, used by a variety of agencies for a variety of purposes, introduce additional institutional complexities into MPLISs, which are not simple to begin with. The key to successful MPLIS development, implementation, and use is a clear, broadly supported plan. This plan should address as many institutional issues (as well as technological issues) as possible from the very beginning. This will allow system users and operators to concentrate on constructive development, and not to become bogged down dealing with issues that could have or should have been foreseen.

Among the institutional issues identified above, several are of major importance as a foundation for a successful MPLIS. Foremost is identifying who will be involved and how they will be organized.

IDENTIFYING PARTICIPANTS

Two key factors should be considered regarding general MPLIS project structure and management. One concerns the decision as to how far to "cast the net". On a conceptual basis, the more people and agencies that are involved, the more comprehensive the resulting system will be, and, therefore, the greater will be the likelihood of the system having the capacity to meet a wide variety of user needs. At the same time, as systems become broader in scope, they also generally become more complex. The second factor concerns the general philosophy of top management regarding the extent to which the MPLIS philosophy is to be integrated into the local agency or jurisdiction.

INTEGRATING MPLIS INTO AN AGENCY

Various local agencies can take two basic approaches to the implementation of an MPLIS. One is to assume that an MPLIS is another tool, technology, technique, or procedure, and to treat it as such. This is similar to the approach used for word processing, copy machines, and stand-alone personal computers. Each of these items improved productivity and improved the quality of the product or service generated.

The second approach is to fully integrate MPLIS into the agency, which means changes -- often radical -- in the way the agency organizes and operates. This latter approach is the one required if the major service and societal benefits of MPLIS are to be fully realized. This approach means a more difficult transition period, because many changes, major *and* minor, are required.

These changes include such items as basic organizational structure, with changed relationships and new lines of command. Individual jobs, sections, and bureaus change. New technology and data responsibilities (for collection, maintenance, storage, and use) are introduced. These, in turn, require not only organizational changes, but also additional training and education of employees. Also, the very nature of LIS technology, with new hardware options emerging every 12-18 months and new software updates every 2-5 years, means that the training and education are continuing, not one-time requirements. Changes of this magnitude in a local unit of government also mean change in operating procedures with other agencies with whom they do business.

Given the power of MPLIS to aid in solving problems related to land and natural resources, the more comprehensive kinds of changes over the long run are the ones we can expect to occur. This suggests that a useful approach is to assume such major changes will occur, and to concentrate management and system development attention on *how* these changes will be made, rather than *if*. Organizations also need to consider how to best move from current systems of handling spatial data to the comprehensive MPLIS models. Again, the complexity of current and proposed systems and the importance of the data, information, and decisions that flow from these systems suggest a gradual, iterative process. Such an approach should be less disruptive, should provide needed technical support during the transition, and should provide the needed time (and other resources) for training of staff.

OVERCOMING BARRIERS

A number of barriers exist to changes that an MPLIS system typically requires. Anyone planning such a system should consider whether these constraints exist in their environment, and should develop plans to deal with each one. Among the potential barriers to watch for are:

- A general resistance to change (resulting from traditional practice, concern over job security, statutory requirements, etc.);

- Lack of familiarity with new or the latest technology (a necessity for system developers to design the institutional framework necessary to support the system);

- Lack of education and training support (necessary at the beginning and on a continuing basis. Education does <u>not</u> stop when the system is successfully implemented);

- Lack of top-level management support (necessary to get project underway and to keep the system successfully operating. Many Wisconsin successes can be traced directly to support of county executives, state agency cabinet secretaries, and at least two governors);

- Demand for a multi-disciplinary effort (not always possible and never easy. The most successful systems in operation, however, have found ways to cooperate on the working level across a variety of disciplines).

This is a limited set of examples. A more empirically based and in-depth analysis of the factors involved in the implementation of MPLIS is presented by Onsrud and Pinto (1993) (Table 17.1).

DATA SHARING

Data sharing is one of the primary justifications for MPLIS systems. This is logical since most data handled by governments (especially at the local level) have a spatial component. Data costs for conversion and data base construction typically account for 75 - 85% of total MPLIS system costs, and maintenance of data bases will continue to require a major proportion of resources (dollars, personnel, time) for operation of the system. Transactional maintenance of the data base is critical if the system is to continue to provide relevant, accurate, timely data for system users.

Ordering of Steps Resulting from Frequency Analysis	Respondents Indicating step was undertaken (%)
Seek and acquire a GIS consultant	55
Prepare informal proposal for GIS introduction	78
Identify GIS user needs	93
Seek staff support for GIS	87
Match GIS to tasks and problems	85
Identify GIS location within organization	83
Prepare formal proposal for GIS introduction	76
Undertake request for proposal (RFP)	80
Conduct a pilot project	76
Enter contract for purchase	96
Acquire GIS technology	100

Table 17.1 Steps undertaken in the acquisition of GIS by local governments (From Onsrud and Pinto, 1993)

It is important that the goal of data sharing be embraced by all participants in the MPLIS system, since it is data sharing through which a substantial portion of the benefits of the MPLIS approach will flow. That is, an MPLIS is not likely to produce any significant reduction in the costs of current activities. Rather, the MPLIS approach will enable the agency to stabilize costs and, more importantly, provide the comprehensive data base necessary to address increasingly complex problems governments are facing.

When agencies are committed to the sharing of data, mechanisms need to be put into place to facilitate sharing. For instance, potential data users will want the answers to several questions: Do the data I need exist? At what scale were the data collected? At what scale can maps be produced from the system? In what format are the data available? On what medium(a) are the data available? And how often are data updated (what is the 'currency')?

DATA COLLECTION

In MPLIS systems, a number of decisions are important to help assure the greatest benefit to as many users as possible. For example, decisions are needed on what data to collect, at what level of resolution, and what currency is required. All parties must commit to a collection process based on cooperation to ensure the common good (Carter, 1992).

STANDARDS

A related institutional factor is the need for standards for hardware, software, and data, the latter being the most critical factor system developers must address. (Hardware and software are just as important but are controlled to a large extent by the vendor companies who produce this technology). Agreements and procedures need to be worked out for the geo-reference framework to be used, positional accuracy, attribute accuracy, data encoding, data exchange (formats), scale of output, and data quality. By thoroughly addressing these standards issues, the quality of the data base will be improved and the exchange of data will be eased.

FUNDING

One of the key institutional issues that must be faced is how to fund an MPLIS. Note that funding of development and funding of operation might not be the same thing. Funding options include cost sharing (on basis of system use, size of data base, geographic area, tax base, etc.), user fees, taxes (property, income, property transfer, recording fees, etc.), bonds, etc. Because each situation where MPLIS systems are developed and operated is unique, developers of each system will need to determine which approach is best. It is wise to involve a broad cross-section of users and policy makers in this decision.

EDUCATION AND TRAINING

Several kinds of education and training are needed to support the development and operation of an MPLIS. Education and access to training are valuable tools for overcoming fear of change (Ventura, 1993). Education of this type can be especially helpful in getting staff to support a project. Training will be needed for staff as soon as a decision is made to implement an MPLIS. The rapidly changing nature of GIS technology will require continuing training and education. This need must be recognized, planned for, and funded, to ensure that staff are fully capable of producing all the efficiencies that this technology allows.

IMPLEMENTATION STRATEGY

MPLIS systems are relatively new and expensive, and are continuing to change rapidly. While the exact nature of future changes is unknown, it safe to assume that they will occur. An implementation strategy should be incremental (to avoid having to do everything at once) and flexible (to accommodate future changes as they occur). Institutional arrangements that support this approach will make it possible to take advantages of the latest innovations, increasing the benefits to all concerned (Haynes, 1993). This approach will also help prevent the surprises of expensive technology becoming obsolete (Haynes, 1993).

These institutional and organizational issues in MPLIS development and use can best be elucidated by a successful model.

WISCONSIN MPLIS MODEL

In Wisconsin, a pilot program was designed to develop and implement a land information system (LIS) with the capabilities to serve a wide variety of users. In focusing on the institutional aspects critical to the success of the project, particular attention was given to the economic analyses that provided the basis for how to organize project participants and which specific technologies to use in the project.

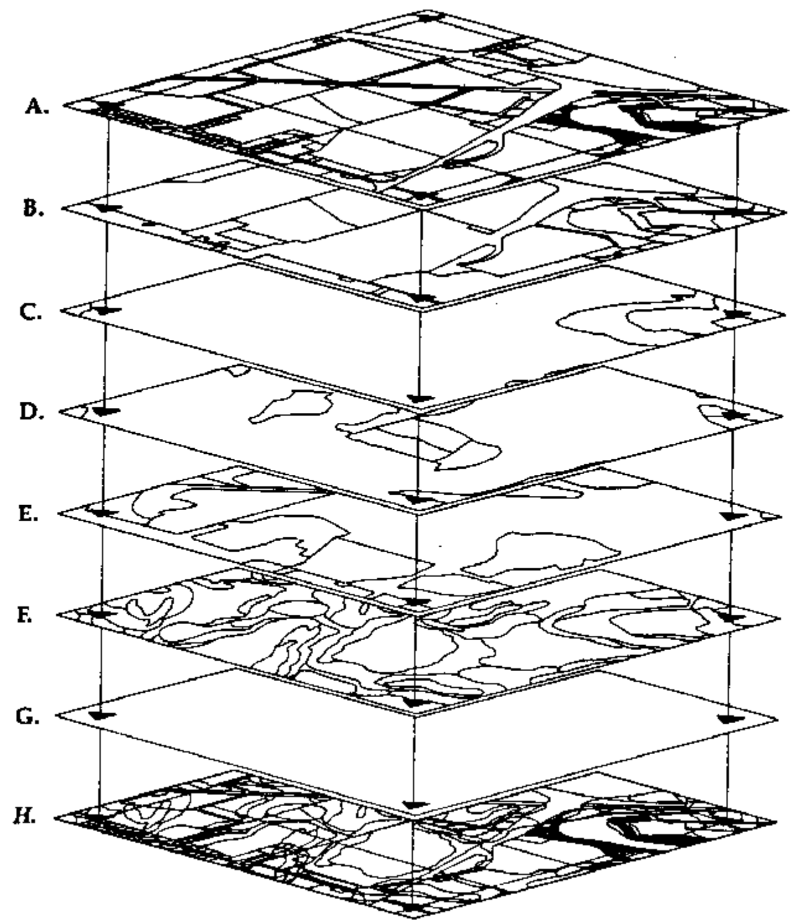
A WORKABLE INSTITUTIONAL FRAMEWORK

Since the early 1970s, Wisconsin has had an active research and development program on the principles and implementation of MPLIS. Beginning with a township pilot study, the effort evolved to include the entire 1,200 square miles of Dane County. Developed as an inter-disciplinary effort referred to as the Dane County Land Records Project (DCLRP), it involved University of Wisconsin researchers and federal, state, and local government officials. The combination helped ensure a balance between theoretical foundation and practical applications (Moyer, 1989). The MPLIS overlay (Figure 17.1) was one of the major contributions of the DCLRP.

Each of the layers in the ideogram represents a separate data file, maintained by a particular office or agency in local, state, or federal government. The seven layers depicted are under the custodianship of five separate offices and represent all three levels of government.

The diagram pulls together much of what we know about MPLISs, including the data they should contain, how they are to be maintained, and the structure of the systems themselves. The layers in the MPLIS are built on the Public Land Survey System (PLSS) tied to the land survey network (i.e., the National Geodetic Reference System, developed by the National Geodetic Survey) that provides the foundation for the entire system. The coordinate locations of survey control monuments serve as the "pins" by which any two or more of the layers can be tied together. This ability to register data -- i.e., link layers to be included in analyses -- is the key aspect of the system. The further ability to link digital data files (i.e., maps and other graphic descriptions) with tabular data files (i.e., tables and other attribute data) is what distinguishes a GIS or LIS from simpler CAD (computer-aided drafting) or CAM (computer-aided mapping) systems.

Many cooperators (Figure 17.1 yields only a partial list) participated in the development of the Dane County MPLIS. Each provided original data that were converted into digital form. They were responsible for pre-conversion data preparation, review of the digital product after conversion, and custody of the digital file when it was ready to be accessed by other MPLIS users.



Concept for a Multipurpose Land Information System

Section 22, T8N, R9E, Town of Westport, Dane County, Wisconsin

Data Layers:	Responsible Agency:
A. Parcels	Surveyor, Dane County Land Regulation and Records Department.
B. Zoning	Zoning Administrator, Dane County Land Regulation and Records Department.
C. Floodplains	Zoning Administrator, Dane County Land Regulation and Records Department.
D. Wetlands	Wisconsin Department of Natural Resources.
E. Land Cover	Dane County Land Conservation Committee.
F. Soils	United States Department of Agriculture, Soil Conservation Service.
G. Reference Framework	Public Land Survey System corners with geodetic coordinates.
H. Composite Overlay	*Layers integrated as needed, example shows parcels, soils and reference framework.*

Land Information and Computer Graphics Facility,
College of Agricultural and Life Sciences, School of Natural Resources

UNIVERSITY OF WISCONSIN–MADISON

Figure 17.1: Concept for a Multipurpose Land Information System (Wisconsin Land Information Newsletter, 1984).

The distributed MPLIS data files can be shared by a wide variety of users at all levels of government, as well as in the private sector. The data shown relate mainly to parcels and resource polygons, but street address data, network data such as roads, railroads, pipelines, power lines, and waterways can (and should) be accommodated as well.

PROOF OF CONCEPT

Dane County is an agricultural county with over 60 % of its area in cropland. The county hosts the University of Wisconsin-Madison, the state's land grant-university, and the state capital. It is the state's fastest growing county. The county has 35 townships, most of which contain 36 public land survey system (PLSS) sections of approximately 640 acres each. Three of these townships, selected as pilot areas for early system development and testing, had a variety of topographical, population density, agricultural, and other features needed to provide a reasonable evaluation of the MPLIS. Among the initial project tasks were to convert data for each layer to digital form and to evaluate options for digitizing, geo-positioning, and land-use determination. Many meetings and other face-to-face contacts helped ensure that each project participant was aware of the activities, data resources, and data needs of all other members of the project.

Early in DCLRP, while data bases were still being designed and built for the three pilot townships, the state government issued a mandate requiring that 54 of Wisconsin's 72 counties each develop a soil erosion control plan (SECP). Specifically, this mandate required that in each affected county:

> "[The county] land conservation committee shall prepare a soil erosion control plan that ... identifies the parcels and locations of the parcels where soil erosion standards are not being met ..."(Wisconsin Statutes, 1981).

This legislation was a major milestone in the development of the Dane County MPLIS. It was the first time that any U.S. program had explicitly required the spatial merger of the location of soil erosion and who was responsible for the potential erosion (Niemann, 1987). It was apparent that the requirements of the erosion control legislation could be met much more efficiently if the relevant digital layers could be put in place for the entire county. Two of the layers developed with the cooperation of the

Dane County Land Conservation Department (LCD) in the pilot areas were soils and cadastre. The DCLRP project team agreed to complete the other necessary data layers for the entire county and to use the MPLIS to develop the SECP (Chrisman et al., 1986).

IMPACTS ON AGENCIES INVOLVED

Several impacts on the LCD are worthy of note. The SECP in Dane County was developed in an automated mode; the other 53 counties used a traditional manual method and produced a hard-copy report. The Dane County Conservationist quickly recognized a number of advantages to using the MPLIS. The Plan could be easily updated, since the digital data base could be used for that purpose just as readily as for preparing the plan in the first place. The digital system could be used to monitor compliance with the plan, both for individual farms and for the county as a whole. However, while the Conservationist was convinced of the positive benefits of the SECP developed from the MPLIS, several of the planning technicians who worked directly with farmers remained skeptical. Fortuitously, while the SECP was being finalized, the federal government passed the Food Security Act (FSA) of 1985, the requirements of which were responsible for generating the support of all of the LCD staff for the MPLIS.

The FSA required cross-compliance between erosion control programs and farm subsidy payment programs of the Federal government. This requirement meant that if a farm operator wanted to receive any farm support payments for crops produced, he or she had to have an approved farm erosion control plan and be carrying out the plan. Those farmers who had not responded to the carrot before were now very interested in responding to the combination of the carrot and the stick. For the LCD, the new FSA requirements meant a major increase in the farm conservation planning workload. The planning technicians quickly realized that the only way they could respond to the intent and spirit of the FSA was by making full use of the MPLIS capacity in their office. The technicians, some of whom had been using manual planning processes for 25 years, soon were strong supporters of the capabilities of the MPLIS.

A number of concrete examples of positive changes in the LCD were the basis for their support. The output of plans per technician increased five-fold, compared to using manual methods. This increase was corroborated by state personnel projections that

16 people would have been required to do manually what three people were able to do with the automated system. Also, during the year, the Dane County LCD prepared 20% of all conservation plans prepared in the state, even though the land area of the county was less than 4% of the state total.

The technicians were happy to point out increased productivity of the office, increased efficiency in their own work tasks, and intangible benefits such as being able to take a laptop computer to the farm, meet with the farm operator, pull data from the data base, develop a draft plan, review it with the farmer on the spot, revise the plan, and print out a hard copy of the plan and leave it with the farmer, all in one visit. The manual system of planning had often required multiple trips.

IMPACTS ON OTHER OPERATIONS

The development of the MPLIS in Dane County also provided the opportunity to measure a number of impacts on the cooperating agencies themselves: improved efficiencies in specific tasks, new costs that implementation of the MPLIS added to the "information budget" of the county, and new capabilities.

EFFICIENCIES IN AUTOMATION

During the development of the Dane County MPLIS, cooperators tested various methods and technologies to determine the most efficient ways to build and operate the MPLIS. These tests, which included examination of several digitizing methods, geo- positioning methods, and land use determination methods, and their results are important not only for developing the most cost-effective system, but also for designing the system structure that is best for operating the system.

	Time (hr)	
Method	Manual	Scanner
Digitizing	6.8	0.5
Editing	3.3	3.3
Total	10.1	3.8

Table 17.2 Time requirements for digitizing Dane County soil maps

One of the data layers converted to digital form was the soils map (Figure 17.1). Two separate procedures were used in the process. First, manual digitizing was used for 62 of the 181 soil sheets in the county. (Each soil sheet covers an area of about 4,300 acres (1,740 hectares)). The remaining soil sheets were converted using scanning technology. The scanning process increased the amount of data digitized in a given time period by a factor of 13 (Table 17.2) . Overall, scanning technology reduced time for digitizing and editing by 62%.

When costs of hardware, software, and miscellaneous items are factored into the analysis, total cost savings of using the scanner technology were even more dramatic than the time factor. The average cost for scanning was only 18% of that of the manual method (Wunderlich and Moyer, 1988). Moreover, a single scanner of the type that produced these results could convert the soils file for all 54 counties (an area of 25.6 million acres; 10.4 million hectares) in one calendar year. This meant that the scanner approach was not only the economical choice, but was also feasible in technical and operational terms as well. The scanner technology employed is now almost 10 years old. Considerable innovations have been introduced, so even more dramatic reduction in soil conservation costs can be anticipated.

A second layer of data converted to digital form was agricultural land cover. Two methods used for this conversion were visual interpretation of 35mm slides and digital classification of LANDSAT Thematic Mapper (TM) imagery. Cost data for the TM process are not strictly comparable to those of the manual process, since earlier TM research was part of another different project from the Environmental Remote Sensing Center (ERSC) at the University of Wisconsin-Madison. When the data had been classified, however, conversions costs (personnel time, processing time, and storage volumes for transporting files to the Dane County system, converting them from raster to vector data structure, and combining these data with other sources) were reduced substantially by use of TM compared to manual interpretation. The cost per square mile (640 acres; 259 hectares) dropped 79 %, from $38 to $8 (Ventura et al., 1988).

A third example of reduced costs resulting from the use of new technology for the Dane County system was in the determination of coordinate locations for survey monuments using Global Positioning System (GPS) techniques rather than traditional ground survey methods. In Dane County, it was necessary to add monuments to provide a survey network of sufficient density to support a modern MPLIS. The survey monumentation process involved the establishment or reestablishment of survey monuments (control stations) in the ground, and the determination of the coordinate location within a mathematical framework for each monument.

Researchers used several methods for establishing coordinate locations, including conventional surveys, inertial surveys, and GPS techniques. A comparison of costs of the various methods was made, supplemented with data from similar evaluations made by the Wisconsin Department of Transportation (DOT).

Typically a conventional survey is the most expensive method, since it usually takes more time and requires the setting of a greater number of monuments in a given area to circumvent "line- of-sight" restrictions. The DOT results showed significant savings (Table 17.3). Now that the full GPS constellation of 21 satellites is available for use, further reductions in GPS costs are being observed. The net result will be order-of-magnitude reductions in survey network costs, when comparing conventional methods with full constellation GPS results.

	Method		
Item	Conventional	GPS	Change
Stations required (no.)	463	81	-83%
Time in field (days)	673	264	-61%
Total cost ($)	$152,410	$95,855	-37%

Table 17.3 Comparison of conventional and GPS survey techniques

The results of MPLIS implementation in Wisconsin reveal some of the impacts that these systems have on government agencies. The new technologies studied produced dramatic shifts in the production methods for major components of the MPLIS. These shifts have implications for the managers and decision-makers in the organizations responsible for developing and operating these systems.

For example, with major resource reductions required for GPS surveys, it may make more sense for the state, rather than individual counties, to take charge of the remonumentation and recoordination program in Wisconsin. Similarly, the relatively large capacity of the digital scanner suggests this technology should be operated at the state level, rather than the county, to be most effectively used. If counties do opt to implement these new technologies, it appears likely that new institutional approaches will be needed, and new uses necessary to optimize the efficiencies of these technologies.

COSTS OF IMPROVEMENTS

The Dane County MPLIS has also demonstrated a number of 'costs' that the MPLIS generates, including coordination, the involvement of many disciplines, and the multiple needs of the many users who must be considered.

Time can be expected to be a major cost. Early in the project, participants agreed to compile records on the amount of time required for each part of the project. This was to include not only such tasks as digitizing and land surveying, but also time required in administrative tasks as well. The results indicated that nearly 25% of the time spent on the pilot project was for administration, including meetings, cooperative agreement development, etc. While the project team agreed that these costs were critical to the success of the project, they recognized that anyone contemplating development of a MPLIS be aware of the magnitude of these institutional investments.

A related cost is the necessity of dealing with a large array of disciplines. This means that each participant must be willing to take the time to learn about the needs of other participants, as well as basic aspects of major disciplines within which other participants are trained. Again, this takes a major time investment, but the resultant increase in understanding makes it worthwhile and probably essential. This understanding, in turn, leads to more useful products and services for each participant.

A fuller understanding of the needs of others often has another impact, the necessity of changing the procedures and methods. That is, because we understand the uses that others will make of the land information from the system, we may logically be expected to make changes that will benefit other users of the system. For example, transportation technicians typically find temporary monuments adequate for use during layout and construction of a highway project. If these same transportation users are involved in an MPLIS, they can likely be persuaded to use a more permanent form of monumentation. The more permanent monuments, while having a slightly higher marginal cost, provide substantial benefits to other users of the survey network and the MPLIS. The key is to be sure there is an understanding of the overall needs, what obligations exist in filling these needs, and how to equitably share the costs of meeting these needs.

NEW CAPABILITIES

Another important impact of an MPLIS is the increased capability it provides -- to do things that are not possible using traditional manual methods. The development of the dynamic soil erosion control plan would not have been feasible if the MPLIS had not already been in place. The flexibility provided by the data structure and software bring impossible tasks into the realm of possibility. This was demonstrated when a last-minute change was made in the rules governing the USDA's Conservation Reserve Program (CRP), just as final Dane County map products were about to be produced using the MPLIS. In less than one hour, one person was able to modify several parameters in the digital model and generated new graphics and tabulations reflecting the new rules. In addition, it was possible to graphically portray the location and amount of acreage affected by the rule change (Gurda et al., 1987). Without the MPLIS, this task would have taken hundreds of hours at best, and quite likely would not have been possible at all.

IMPACTS AT THE FEDERAL LEVEL

The development of MPLIS/GIS is continuing to have major impacts at the national level in several ways: investments at the federal level in LIS/GIS technology and in digital data sets, and substantial support by the federal government for standards development. On April 11, 1994, President Clinton issued an executive order calling for the establishment of a National Spatial Data Infrastructure (NSDI) from which all levels of government would benefit (Office of the President, 1994).

The development and use of MPLIS in the federal government is increasing rapidly. A survey of GIS use found that 37 of the 44 agencies responding were either using or planning to implement such a system (FICCDC, 1988). Twelve of the organizations said they were already using a GIS mode and 31 reported they were currently using existing data sets from at least one other agency.

Federal expenditures for MPLIS activities are also increasing rapidly. Expenditures for "electronic mapping databases" of $99 million in FY 88 were expected to increase to $200 million by FY 92 (Arthur, 1989). Total expenditures for the 1988-92 period were estimated at $760 million. (These are civilian expenditures only; national security expenditures are not included.) A recent review of these 1988 estimates by the National Research Council's Mapping Sciences Committee indicates that current estimates of federal mapping initiatives are at least twice as great as those in OMB Bulletin 88-11 (on which Arthur's estimates were based) indicated (Mapping Sciences Committee, 1993).

A number of individual federal agencies are also putting major resources into LIS/GIS development. The USDA Forest Service, which manages nearly 200 million acres (81 million hectares) of public lands, had plans to have an agency-wide GIS in operation by the late 1990's. Expenditures in information technology by the Forest Service totaled $125 million by 1989, with plans to double this investment by 1992 (Hartgraves, 1989; Arthur, 1989). Current Forest Service plans have increased the planned expenditures several-fold. Project 615, a plan that would provide for the purchase of workstations and software for a variety of GIS applications, accounts for a large portion of the increase. The project has grown from about $400 million to nearly a billion dollars in value (Marsan, 1991; Baerson, 1992).

The US Bureau of Land Management (BLM) is also making substantial investments in GIS technology. One portion of the BLM system alone, the Automated Land and Minerals Records Systems (ALMRS), under development for a number of years, carries a price tag that has risen from an initial estimate of $150 million to $328 million (Bass, 1989; Moore, 1992). If all options on the contract awarded in 1993 are exercised, the 10-year contract could total $400 million (*GIS World*, 1993).

Another federal activity providing coordination for development and operation is the work of the Federal Geodetic Control Subcommittee (FGCS) of the Federal Geographic Data Committee (FGDC). The National Geodetic Survey (NGS) serves as the secretariat for the FGCS, which consists of representatives from 11 federal agencies with geodetic and related land survey activities and interests. One of several FGCS projects currently underway is the preparation of this *GUIDEBOOK*.

Federal agencies also play several important roles in state and local governments. NGS provides technical assistance, through a system of 26 state advisors, to state and local agencies. It is supporting a number of pilot projects through funding and direct services to state and local governments engaged in the development of MPLIS:

- Matanuska Susitna Borough, Alaska
- Jefferson County, Colorado
- Orange County, Florida
- Wyandotte County, Kansas
- Calcasieu and Jefferson Parishes, Louisiana
- Spartanburg County, South Carolina
- Dane County, Wisconsin

As a result of these pilot projects, numerous state and local agencies have made major strides in developing MPLISs. NGS shares the lessons learned in these pilot projects to foster further savings and to help avoid repeating 'mistakes.'

IMPACTS ON THE PRIVATE SECTOR

Since MPLIS activities are still in their infancy, it is difficult to assess impacts this technology has on the private sector. A couple of phenomena, however, suggest that the private sector is likely to play a role that will be significant in terms of both money and systems development.

First, GPS activities are expanding rapidly. Numerous major commercial entities are marketing GPS hardware and software. Surveying companies are adding GPS to their businesses. The rapidly expanding demand, particularly at the local and state government level, for a more dense geodetic network and for coordinates on each survey monument all point to continued growth in GPS for some years to come. Second, other companies are looking for ways to become part of the rapidly expanding MPLIS field.

These effects support our contention that an effort undertaken with the vast institutional and economic potential of LIS/GIS in mind is much greater than the sum of its parts. In fact, the Dane County MPLIS successes bolstered state-wide efforts -- the Wisconsin Land Information Program -- to implement LIS.GIS in local government.

WISCONSIN LAND INFORMATION PROGRAM

The experiences in developing the Dane County MPLIS support the hypothesis that institutional, not technical, issues are the most critical in assuring that MPLISs are successfully implemented. On this premise, Wisconsin land-use professionals crafted the substance of a Wisconsin Land Information Program (WLIP). A major thrust of the Program is to help overcome institutional barriers.

The WLIP was established by the Wisconsin Legislature in June of 1989. It was created to provide incentive, technical support, and financial support to counties and other units of local government in modernizing (usually automating) their land records systems. The Program was the result of two years of study and development by the Wisconsin Land Records Committee (WLRC), appointed by then-Governor Anthony Earl (Wisconsin Land Records Committee, 1987; Merideth et al., 1990).

WLRC was a broad-based committee that grew out of an earlier statewide consortium of "concerned professionals" interested in land information system improvement. The 33 members of WLRC represented all geographic areas of the State and a wide range of professions. The Committee was supported by 12 subcommittees with equally broad professional representation. The nearly 100 people involved were thus well suited to address the breadth and complexities of MPLIS development.

WLRC reached agreement on a number of major issues as they identified the elements of the Program.

- Land information systems are and will continue to be developed primarily by local and state governments;
- Technology involved will continue to change;
- A mechanism is needed to manage these changes (i.e., to facilitate communication and coordination);
- Significant amounts of state funds are not likely to be made available for land records improvement programs.

On the basis of these conclusions and much deliberation, WLRC recommended that a formal WLIP be established, consisting of four main components (Figure 17.2). This program was adopted by the Legislature and signed into law. The following year, the Legislature established a means to fund the

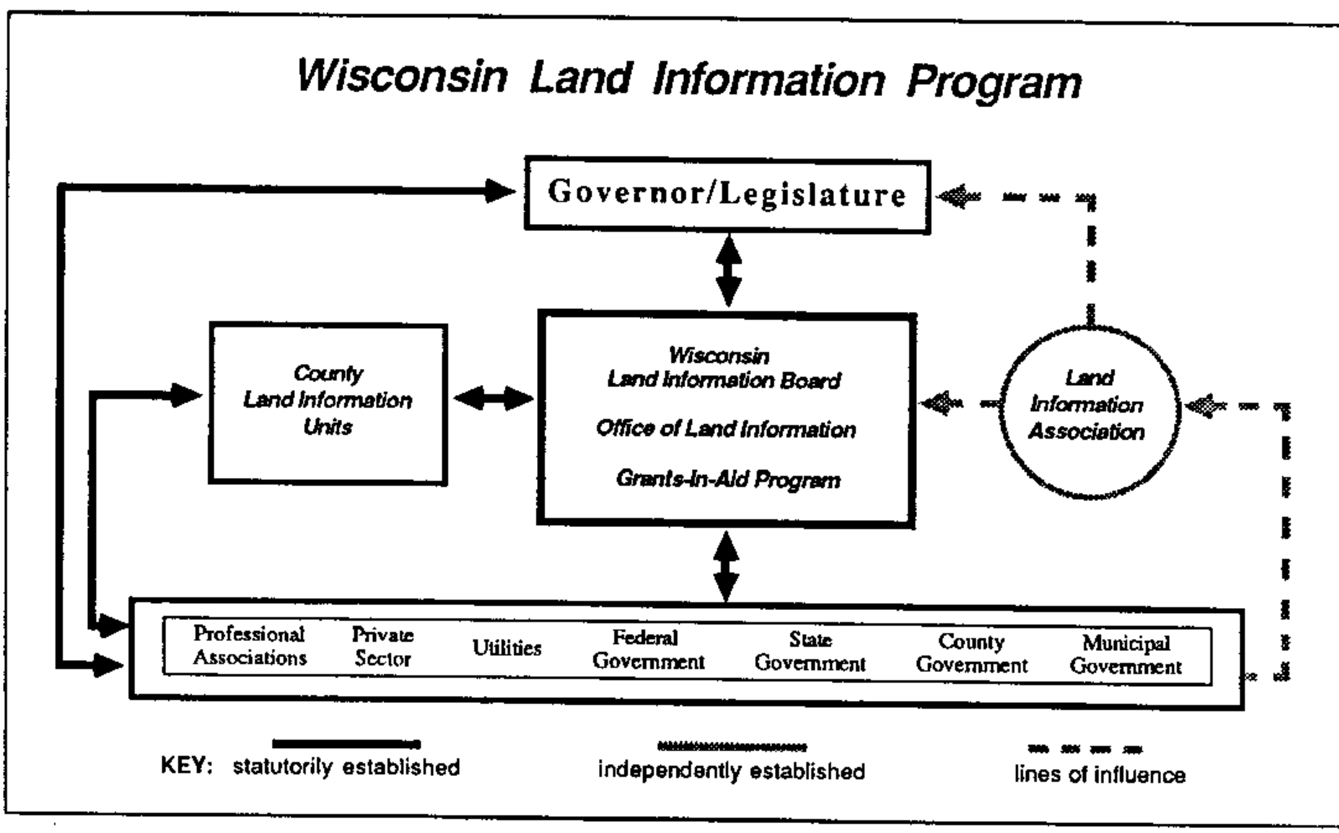


Figure 17.2: The concept of a state land information program like Wisconsin's consists of a state oversight Board, a statewide professional organization, individual county offices, and the users of land information.

WLIP: the fee for each record filed with the Register of Deeds was increased by $6, $4 of which was to be retained by each participating county and $2 to be contributed to a competitive grants program for which all local governments are eligible. By early 1994, about $14 million had been retained by Wisconsin's 72 counties and $8 million had been made available for the competitive grants program and for management of the overall program.

The Program, overseen by the Wisconsin Land Information Board, mandates that each participating county name an individual, committee, or office as that county's Land Information Office. It also mandates that state Departments of Transportation, Natural Resources, and Agriculture develop and maintain a schedule for integrating automation into their operations.

WISCONSIN LAND INFORMATION BOARD (WLIB)

The WLIP is overseen by the Wisconsin Land Information Board, a 13-member policy board appointed by the Governor. The WLIB is attached to the State Department of Administration, but is independent in matters of budget and policy. The Board advises policymakers on programs and budgets, recommends legislation, inventories land records and land information systems in the state, develops standards and guidelines for specific components and overall system operation, approves county land record modernization plans, and develops and operates the grants program to aid local government implementation of LIS.

OFFICE OF LAND INFORMATION

The WLIB now has the authorized staff of four. State agencies with land records responsibility have been urged to provide additional technical assistance to support the Office. Among the agencies who have responded affirmatively, the Department of Transportation has designed a GPS-based high-precision geodetic network for use by local governments.

LOCAL LAND RECORDS AGENCIES

For counties to participate in the WLIP, they must, by County Board resolution, designate a land information committee, office, or officer (LIO), whose function is to coordinate local land information system activities. All grant requests from the county or other local governments within the county and grants from the state must be channeled through the LIO. And they must submit a county modernization plan to the WLIB for approval. Each plan must address five technical foundational elements (geographic reference frameworks; parcels; wetlands; soils; and zoning) and three institutional foundational elements (institutional arrangements; communication, education and training; and public access arrangements) (Holland, 1992).

They also agree to submit an annual report on their expenditures by each foundational element. Because WLIP is in its initial stages of implementation of county land information systems, one would expect large investments in the establishment of the technical aspects of the reference framework and the modernization of tax and/or ownership parcel information (Figure 17.3). Yet in addition to these considerable investments in the technical elements, many counties are also active in all of the various institutional elements (Figure 17.4).

WISCONSIN LAND INFORMATION ASSOCIATION

Though not part of the formal legislative recommendations, a suggestion by WLRC strongly urged that an independent Land Information Association (WLIA) be established. This association, formed in 1989, has served as the most critical component in the successful operation of the WLIP. The membership of this advocacy group now includes about 700 individuals, private firms, and government agencies who are actively work for and support LIS modernization in Wisconsin. The association is built on the grassroots support that lead to the initial formation of WLRC, and has been integral in supporting enabling and remedial legislation and securing long- term LIS improvements that will benefit all segments of society.

SUMMARY AND CONCLUSIONS

One of the least understood, least discussed, and most important aspects of MPLIS systems is the institutional framework in which these systems are developed, implemented, and used. Institutions and institutional arrangements are central to successful MPLIS operation. Unless institutional issues are dealt with in an aggressive manner, the most technically sound MPLIS can have disappointing results. Conversely, care in developing the institutional and organizational aspects of an MPLIS system will help ensure that benefits of the technology are maximized.

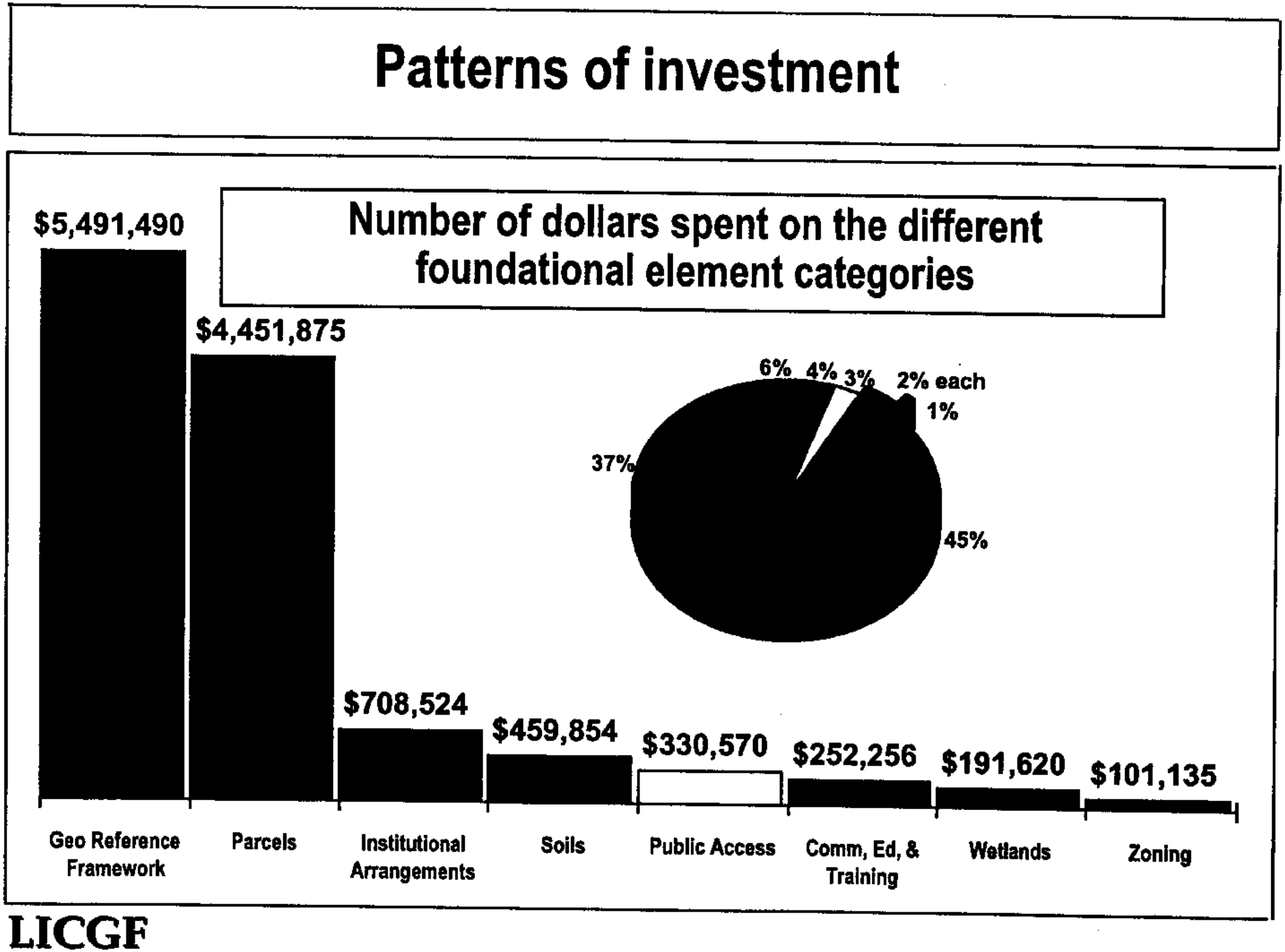


Figure 17.3: Most investments (by amount) by Wisconsin counties are in the technical foundational elements of modernization.

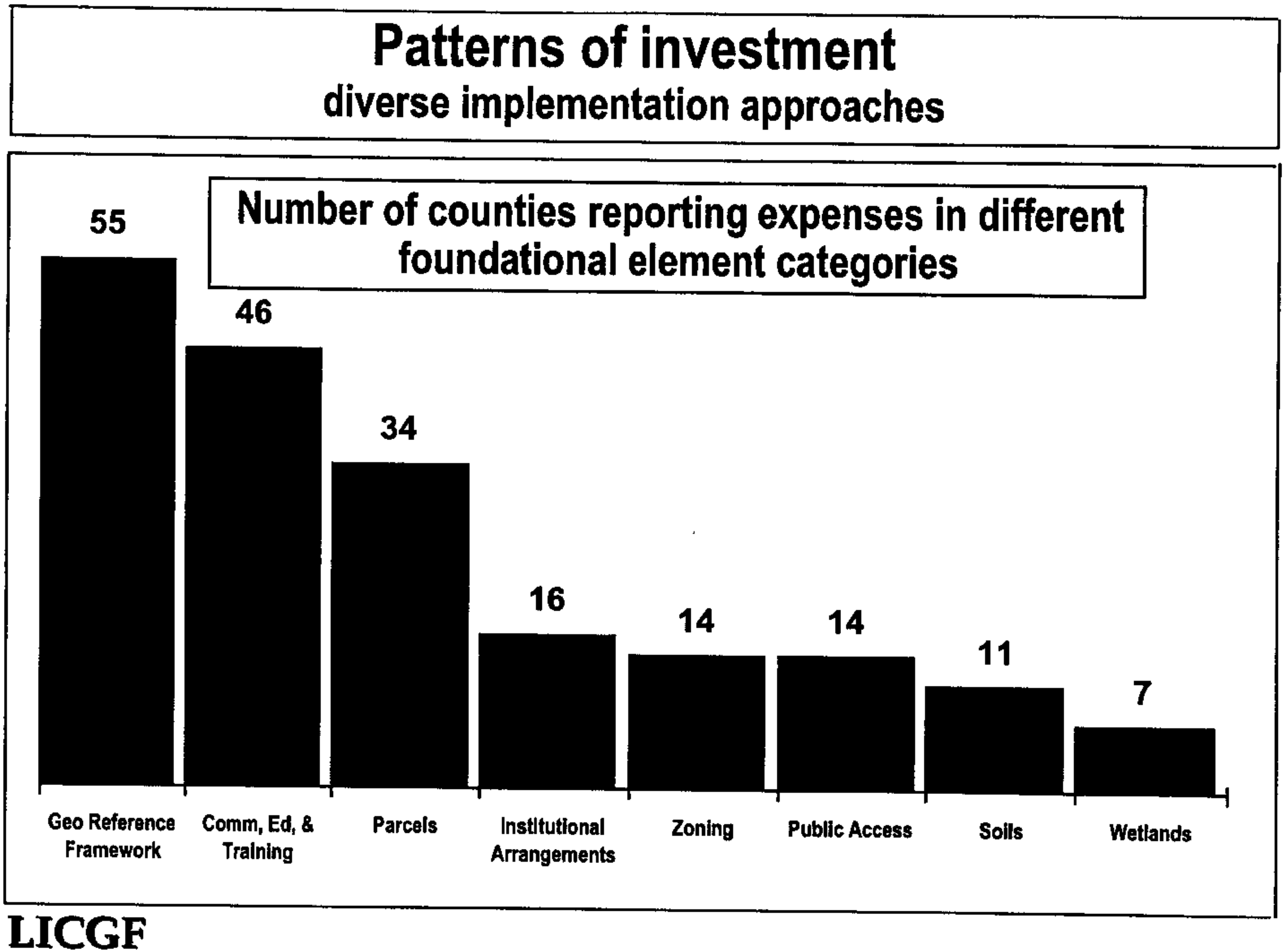


Figure 17.4: Many Wisconsin counties are active in the institutional foundational elements.

Institutional issues and the economic evaluation of the benefits and costs of MPLIS systems are closely linked, and the rigorous and long-term assessment of the impacts of MPLIS is a complex and difficult task. By their very nature, MPLISs necessitate that we look at new ways of doing traditional tasks and sometimes organize ourselves in new ways to carry out these tasks.

Several research and development efforts in Wisconsin have identified a number of institutional impacts of MPLIS implementation and operation:

- New technologies such as GIS often result in major shifts in production methods for major components of an MPLIS. For example, the speed and capacity of technologies such as GPS suggest shifts from county to state level for design, acquisition, and operation of some of these technologies. This may be necessary when local governments do not have sufficient volumes of work to keep equipment operating at efficient levels.

  Alternatively, if counties choose to operate some of the technologies involved in MPLIS systems, some new institutional arrangements may be necessary -- e.g., groups of counties cooperating in such activities as data acquisition and GPS surveying projects.

- By their very nature, MPLISs result in much closer cooperation among users of the system. Such results have been identified for county and federal government personnel. Some offices now have a local area network (LAN) providing federal and county employees with access to a common hardware system that contains a common data base.

- A better understanding of the needs of other MPLIS users often requires changes in methods and procedures used. Users make changes in the way they carry out tasks, and can logically expect other users to reciprocate. Examples range from creating a strategic plan for identifying essential permanent survey monuments to making major changes in data collection and handling techniques to meet the needs of new programs such as the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA).

An analysis of the MPLISs implemented in Wisconsin indicates that most of the impacts are positive in nature and substantial in amount (Kuhlman, 1994). These early results suggest a bright future for land information systems that help address the myriad issues facing policymakers and technical personnel in a wide variety of land and natural resource agencies.

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19 MAPPING: METHODS AND PROCEDURES

Alan P. Vonderohe

INTRODUCTION

This chapter presents an overview of large-scale topographic and parcel mapping methods. Procedures and technology are described. Chapter 2 of this guidebook serves as an introduction to mapping concepts within the context of multipurpose land information systems, Chapter 12 describes the nature and use of base maps, and Chapter 13 describes the nature and use of parcel maps. Here, the emphasis is on acquiring and updating topographic maps (base maps) and parcel maps. As with the rest of this guidebook, the audience for this chapter is local government professionals.

TOPOGRAPHIC MAPPING

Topographic maps depict natural and cultural features on the earth's surface. They also depict relief, most often by curving contour lines. These maps are used not only as sources of information within themselves, but also as a reference base for developing and integrating other information. For example, to determine the number of buildings on a parcel, a parcel map might be overlaid with a topographic map at the same scale.

Computerized or digital topographic maps are often separated into components or layers, with the relief being represented as contours or as a surface model and other features divided into classes such as highways and streets, rivers and streams, buildings, and transmission lines.

Perhaps the most familiar forms of topographic maps are the United States Geological Survey (USGS) series. The 1:24,000 scale, 7 1/2 minute, USGS quadrangle maps are popular and are used for a wide variety of purposes, including natural resource inventory and land-use mapping in rural areas.

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Figure 19-1 is an example of a topographic map prepared for the Southeastern Wisconsin Regional Planning Commission. It is typical of the topographic maps which support planning, resource and facilities management, and taxation in that part of Wisconsin.

MATCHING SCALE TO USE

The National Research Council (NRC) in 1983 suggested topographic map scales ranging from 1:600 to support urban parcel mapping to 1:24,000 to support resource inventory. Such maps usually carry contours at intervals ranging from 1 to 20 feet. In 1989, the joint Geographic Information Management System Committee (GIMS) of the American Society for Photogrammetry and Remote Sensing (ASPRS) and the American Congress on Surveying and Mapping (ACSM) published geographic data base guidelines for local governments. The guidelines contain recommendations similar to those of NRC and include a figure, similar to Figure 19-2, of data items and the range of scales at which they are typically mapped.

The selection of map scale is critical in any project. The scale of a map places a limit on its use, not only from the standpoint of interpretation and quantitative analysis, but also from the standpoint of integration of the map data with data from other sources. These factors and others need to be considered, within the context of present and potential future uses, when selecting the scale of any topographic map to be produced. Tables 19-1 and 19-2 contain summaries of map scales and contour intervals that are suggested by ACSM and NRC, depending on use of the resulting map material.

In an MPLIS, the planimetry on a topographic map often serves as a base for developing parcel maps. Therefore, the scale of topographic mapping might be fixed by the scale of the parcel overlay.

In the digital world, a map has no apparent fixed map scale because the locations of features are typically described by coordinates which can be displayed at any scale. However, all digital maps have *source scales* or levels of accuracy that limit how they can be combined with other maps. Digital maps can be digitized from original hardcopy maps at fixed scales. Alternatively, topographic maps can be compiled directly in digital form either by using data gathered from ground-based surveys or

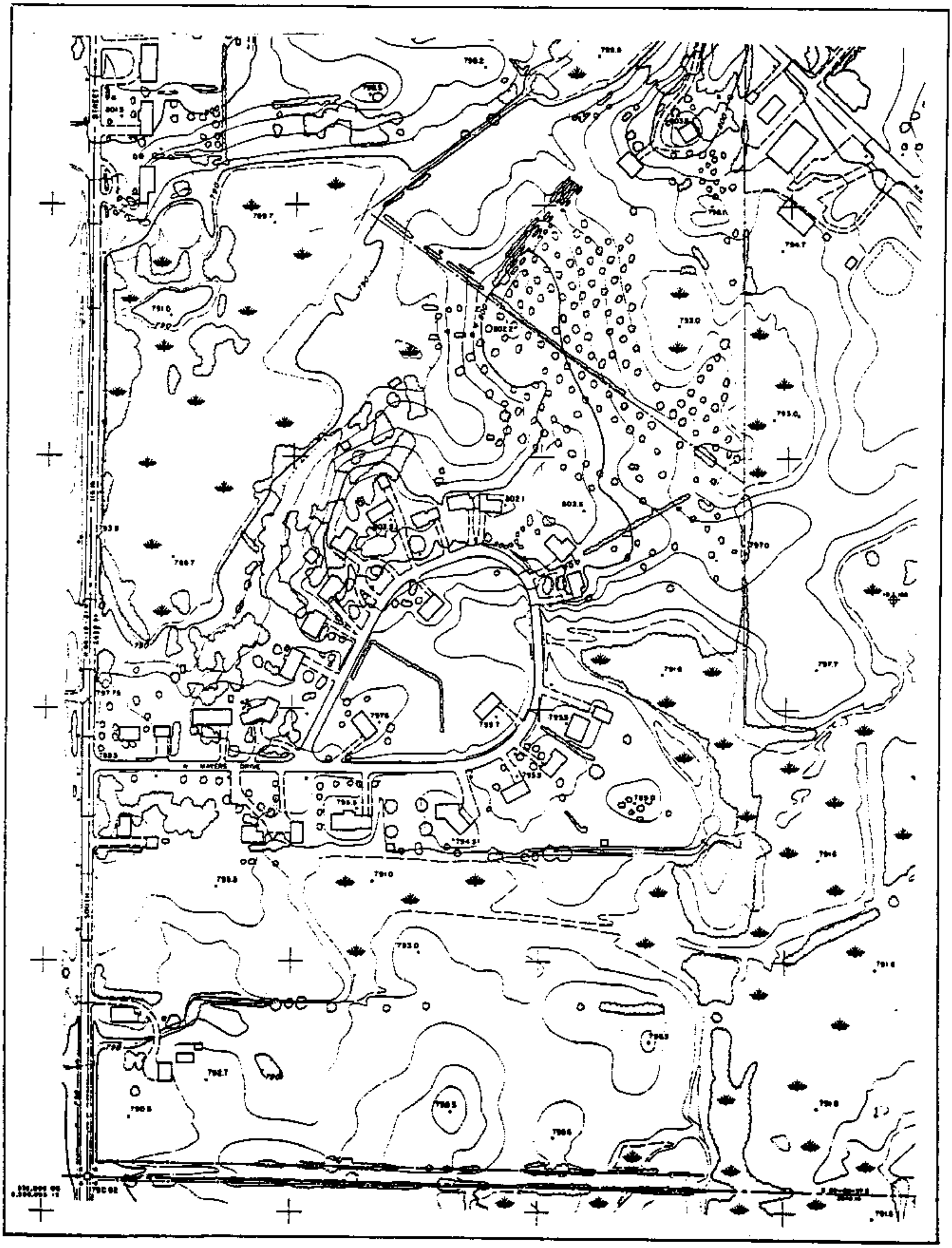


Figure 19-1: *A portion of a typical large-scale base map prepared for the Southeastern Wisconsin Regional Planning Commission (courtesy of SEWRPC).*

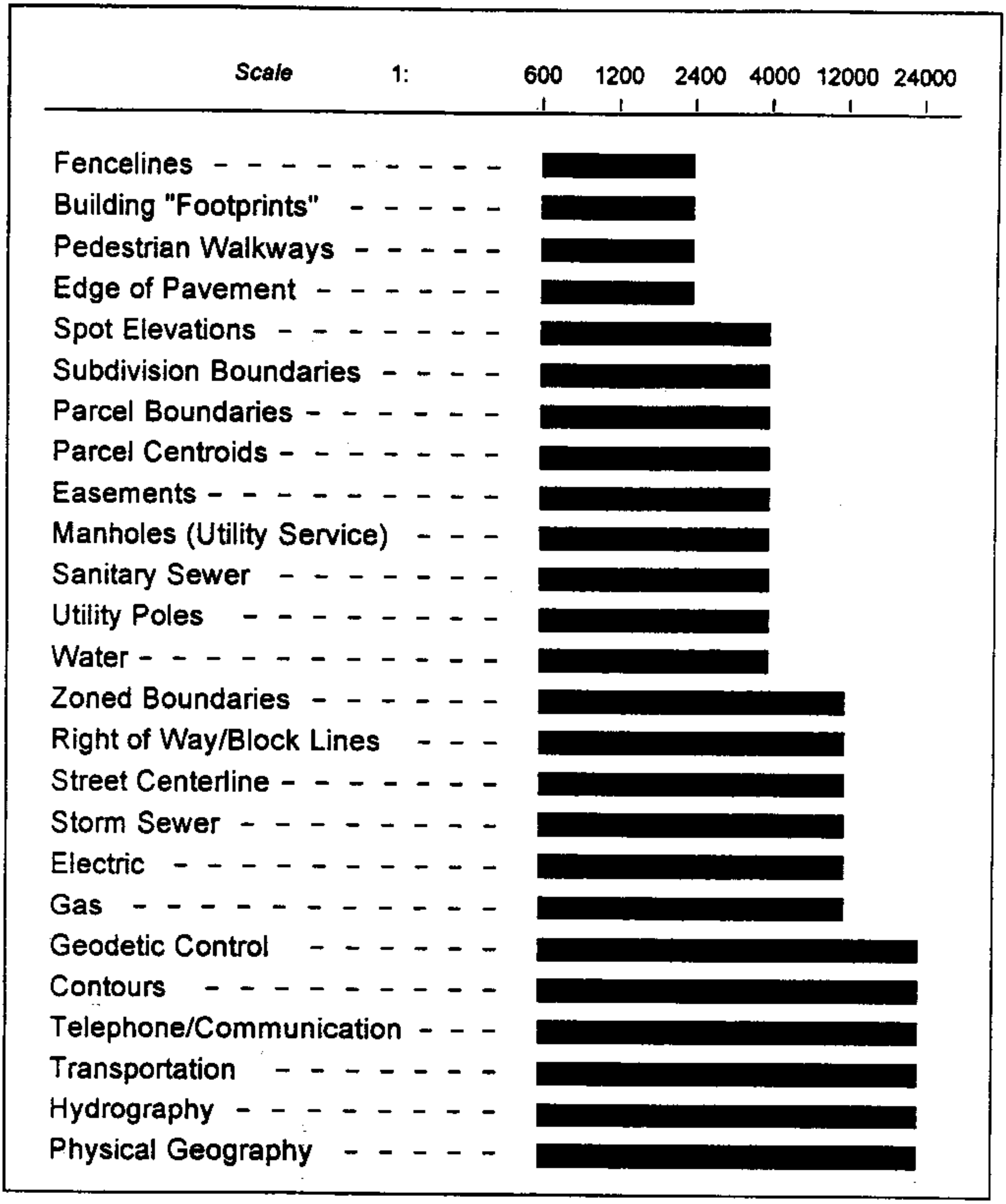


Figure 19-2: *Typical scale ranges for depiction of certain map features (from Vonderohe, et. al., 1991) (after ACSM-ASPRS (1989)).*

USE	SCALE	CONTOUR INTERVAL
Highway and Street Engineering and Water Support	1:24,000 (Master Plan) (Watershed area)	10-20 feet
	1:2,400 (Preliminay location work)	5 feet
	1:480 - 1:1,200 (final design)	1 or 2 feet
Storm and Sanitary Sewer Engineering	1:4,800 (Floodplains) (Outlying areas)	2-5 feet
	1:2,400 (Municipal)	2 feet
Traffic Engineering and Street Lighting	1:9,600 - 1:24,000 (Generalized studies)	
	1:1,200 - 1:2,400 (Planning and engineering)	
	1:240-1:480 (Problem areas)	
Planning	1:9,600 (Regional)	As appropriate
	1:2,400 (Municipal)	As appropriate
	1:120 (Detailed)	As appropriate
	Various others depending on purpose	As appropriate
Tax Assessment	1:4,800 (Rural)	
	1:1,200 - 1:2,400 (Suburban)	
	1:480 (Municipal)	
Utilities Location and Management	1:480	
City Surveys	1:480 - 1:1,200	1 or 2 feet
Parks and Recreation	1:24,000 (Area-wide)	
	1:1,200 - 1:2,400 (Site Specific)	2 feet
Emergency Services	1:4,800; 1:9,600; or 1:24,000 (Depends on size of community)	

Table 19-1: Topographic Map Scales and Contour Intervals for Certain Uses (from ASPRS-ACSM (1987))

Customary		Metric	
Map Scale	Contour Int.	Map Scale	Contour Int.
1:600	1, 2 ft	1:500	0.5 m
1:1,200	1, 2, 5 ft	1:1,000	0.5, 1 m
1:2,400	2, 5 ft	1:2,000	0.5, 1, 2 m
1:4,800	2, 5, 10 ft	1:5,000	0.5, 1, 2 m
1:12,000	5, 10, 20 ft	1:10,000	1, 2, 5 m
1:24,000	5, 10, 20, 40 ft	1:25,000	2, 5, 10 m

Table 19-2: Appropriate Contour Intervals for Certain Map Scales

by using photogrammetric methods. For maps derived photogrammetrically, their source scale is determined by the scale of the aerial photography and the photogrammetric equipment and methods used for their compilation.

TOPOGRAPHIC MAPPING METHODS

Very large-scale (i.e., 1:240 and larger), site-specific, topographic maps can be developed from ground-based surveys with instruments that make measurements and record the information in electronic notebooks or data collectors. Codes for the features being mapped are also electronically recorded. Data from the collectors are later downloaded, analyzed, and processed into maps.

Topographic maps at scales smaller than 1:240 are nearly always made using photogrammetry, which includes methods for obtaining spatial information from photographs. Photogrammetric methods are cost effective at these scales because aerial photography captures detailed information over large areas. A photograph, itself, is not a map because it has geometric distortions which can cause its scale to vary widely throughout the image (see Chapter 2).

ACQUISITION OF AERIAL PHOTOGRAPHY

In order to prepare maps, strips of overlapping aerial photographs are acquired with highly accurate, large-format mapping cameras (see Figure 19-3). Any two consecutive overlapping photos in a strip are known as a "stereo pair" because when they are viewed simultaneously - one by the left eye and one by the right -a three-dimensional image is perceived (using the same principle as that of 3D movies). In order to ensure stereoscopic coverage of an entire strip, consecutive photographs are overlapped (called "end lap") approximately 60% as shown in Figure 19-3.

If a large area is to be mapped, successive adjacent strips of photos are acquired, forming a block as shown in Figure 19-4. Once again to ensure complete coverage, adjacent strips are made to overlap (called "side lap") by approximately 20-30%.

AERIAL MAPPING CAMERAS

The cameras used to obtain aerial photography for mapping purposes are constructed to rigid specifications. The cameras

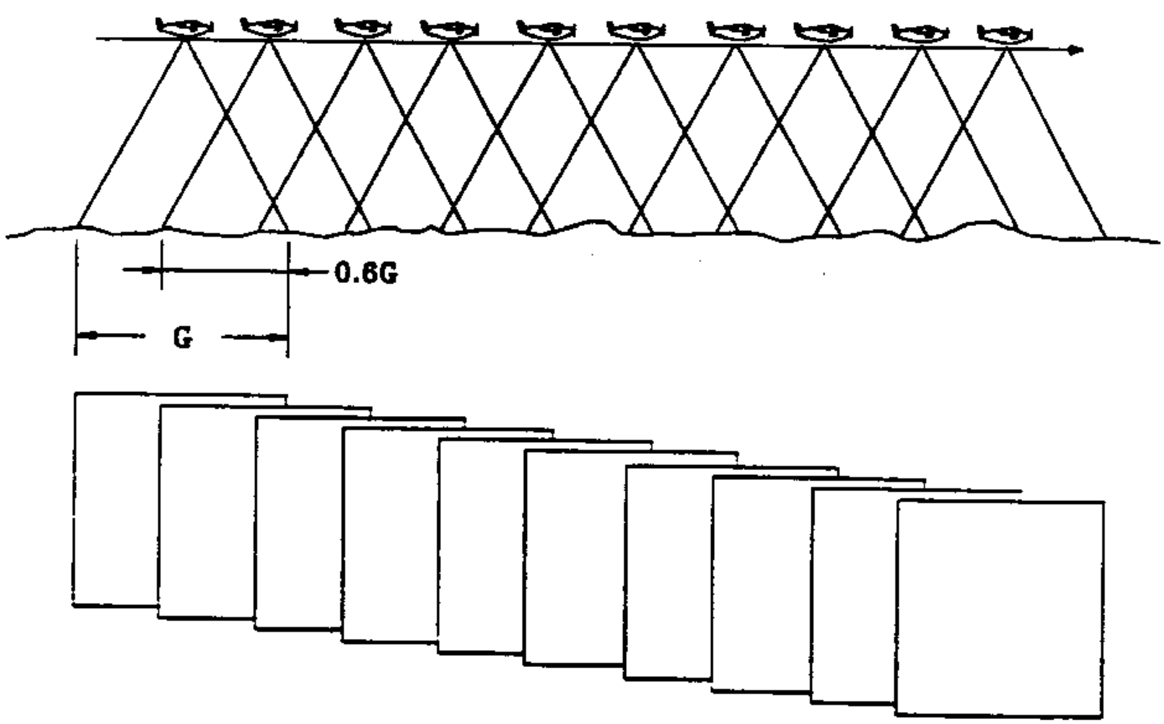


Figure 19-3: A strip of aerial photos showing end laps.

accept large format film (typically 9 inch X 9 inch photo frames). Their lenses are designed to minimize distortion and their internal components are especially stable. Typically, there is a mechanism, such as a vacuum applied through the camera's platen, for flattening the film during exposure. Aerial mapping cameras are periodically calibrated to determine their residual lens distortions and the exact geometric relationships of their internal components.

The most common lens for mapping photography has a 6-inch (152 mm) focal length. Lenses with focal lengths of 3.5 inches (89 mm), 8.25 inches (210 mm), and 12 inches (305 mm) are sometimes used (Wolf 1983).

Aerial mapping cameras are typically mounted in gimbals so that by monitoring level vials during flights, adjustments can be made to keep their optical axes nearly vertical. During a mission, a mapping camera's cycle (e.g., film flattening, shutter trip, film advance) is usually driven by an electronic intervalometer that is keyed to the aircraft's speed, the extent of the ground coverage of a photo in the direction of flight ("G" in Figure 19-3), and the end lap between consecutive photos in a strip. The camera automatically includes in each exposure information such as the date, time, and identification number of the photo. Advanced mapping cameras include a feature called "image motion compensation" which accounts for the fact that the aircraft moves while the shutter is open.

STEREOPLOTTERS AND MAP COMPILATION

If a pair of photographs is oriented properly when viewed in stereo, a three-dimensional "model" of the features in the photos will be perceived. When a minimum number of geodetic control points (whose coordinates are known) can be seen, the model can be accurately positioned with respect to the earth's surface. It will then have appropriate orientation and consistent scale for mapping.

Highly specialized, precise instruments called "stereoplotters" are used to create "true" stereomodels. A stereoplotter first reproduces the internal geometry of the mapping camera. This process is called *interior orientation*. The two photographs are then translated and rotated with respect to one another in order to reproduce their relationship in space at the time of photography. This process creates the stereomodel and is called *relative orientation*. The stereomodel is then scaled and leveled by bringing it into correct alignment and attitude with respect to

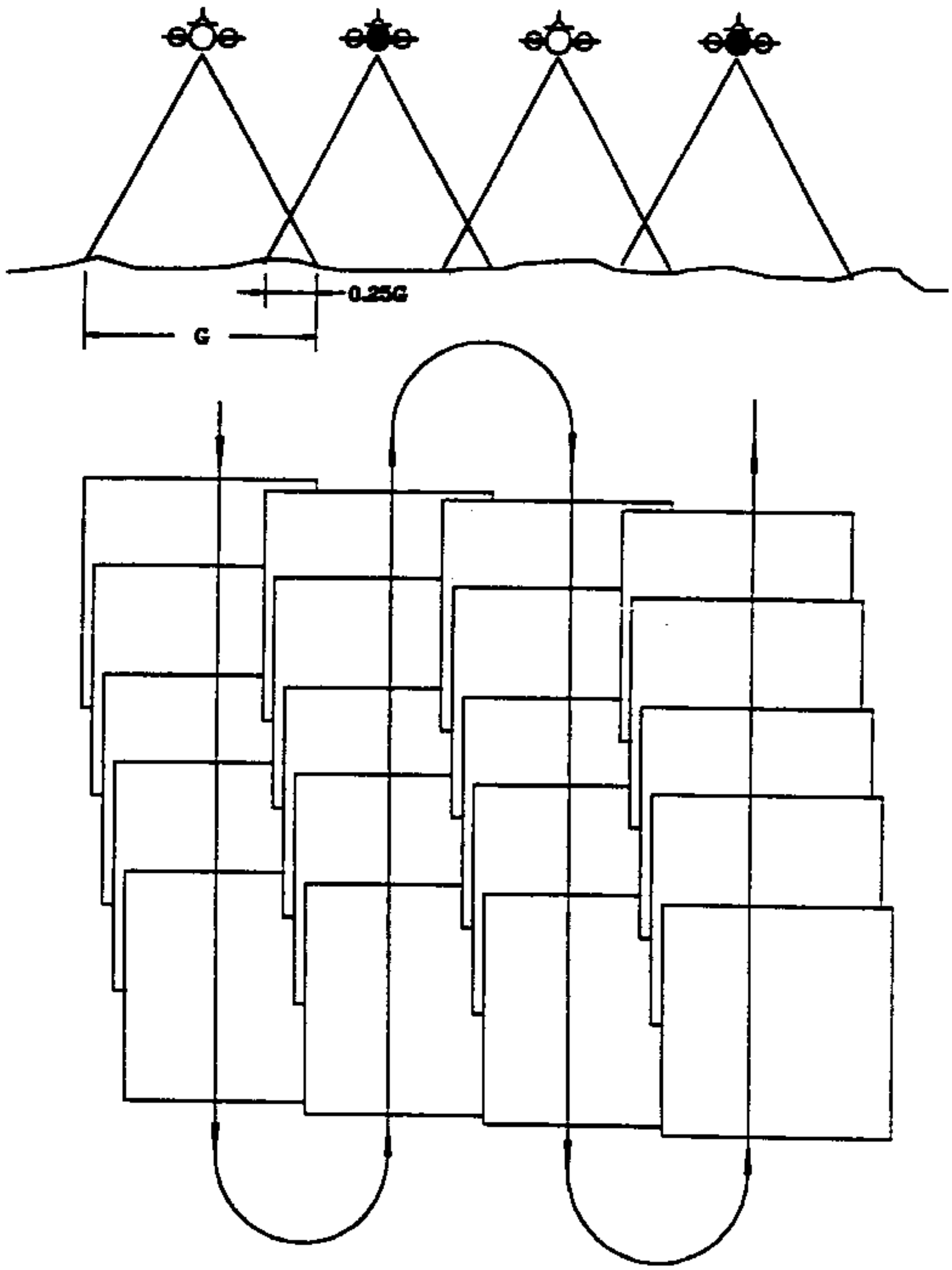


Figure 19-4: Sidelapping adjacent strips forming a block of photos.

horizontal and vertical geodetic control points in the mapping space. The scaling part of *absolute orientation* is accomplished by adjusting the separation between the two photos. Leveling can be achieved in different ways depending upon the instrument, but one way is to rotate the two photos in unison.

Features and contours in the stereomodel are then traced by an operator to produce a map. Many photogrammetric maps are now compiled directly in digital form with individual themes being assigned to separate files.

If a surface model (such as a triangulated irregular network (TIN)) is to be generated in lieu of contours, the stereoplotter operator will typically map selected spot elevations along with critical terrain features such as depressions, high points, ridge lines, valley lines, and terrain breaks. Alternatively, if a digital elevation model (DEM) is required, the stereoplotter can be used to acquire equally spaced profiles that cover the terrain with a dense uniform grid or *raster* of elevation values.

In a modern *analytical stereoplotter*, a computer emulates all of the orientations and, thus, mechanical means of orientation are not necessary. Analytical plotters provide freedom from restrictions from the camera and its internal orientations.

Digital or "soft-copy" photogrammetry concerns photogrammetric aspects of digital images which are usually produced by scanning photographs. Recent technological advances have led to soft-copy systems that display stereopairs of photos on screens of workstations and personal computers. These systems provide various photogrammetric capabilities, including topographic mapping. They hold promise for reducing the large costs of high-quality photogrammetric technology.

Whether digital or hardcopy, the resulting map data will typically need cartographic attention. Building corners need to be squared off, contours need smoothing, etc. Most computer-assisted photogrammetric mapping systems provide effective tools for helping with these editing operations. A common final product is a black-line positive on a polyester sheet. The process of producing the final deliverable from the compilation manuscript is sometimes referred to as "map finishing." If the map has been compiled digitally, an electronic file can be delivered. Hardcopy maps can then be produced at will with a high precision plotter.

ORTHOPHOTOGRAPHS

An *orthophoto* is a photograph that has had the distortions caused by tilt and relief removed (see Chapter 2). It is a photographic image that has consistent scale throughout and can be used as a map. Orthophotos combine the advantages of consistent scale with the interpretive aspects of photography. They contain all the detailed information of a photograph, as opposed to only the selected information depicted by maps. An orthophoto can serve as a base for compilation of contours and features to produce a *topographic orthophotomap* without the need for all the line work and planimetric detail on standard topographic maps.

Orthophotos are created from aerial photographs by a process known as "differential rectification." This process adjusts a photographic image, a small piece at a time, using information about the camera's orientation in space and the relief of the terrain. Two methods for performing differential rectification will be briefly described. Both of these methods require that a DEM or dense raster of elevations be available. The DEM is typically produced on a stereoplotter from the same photographs that will be used for the orthophotos.

Off-line orthophoto production uses a computer-driven orthoprojector which contains both the original aerial photo negative and an unexposed film sheet that will become the orthophoto negative.

In off-line orthophoto production, the aerial photo is mounted in the projector to account for tilt. The projector contains a narrow exposure slit for transferring the photo image. The orthophoto negative is exposed through this slit in a series of parallel scan lines that correspond to the profiles or rows of elevations in the DEM. The computer varies the projection distance along each profile according to the recorded elevations, thus accounting for relief displacement as the image is transferred.

Digital orthophotos are produced using image processing techniques. An aerial photo is scanned in rows with a microdensitometer that records a value for the light intensity at each individual scanning increment or picture element ("pixel"). The result is a dense, uniform grid of relative light intensities that represent the aerial photo in digital form. An algorithm is then run that "re-samples" this digital image according to the tilt of the photo and the relief represented by the DEM. A new intensity value for each pixel is derived from surrounding pixel values and from displacements computed for tilt and relief. The resulting digital orthophoto can be displayed on computer screens, subjected to further computer analysis, used to expose film negatives, or plotted with a high-quality raster plotter.

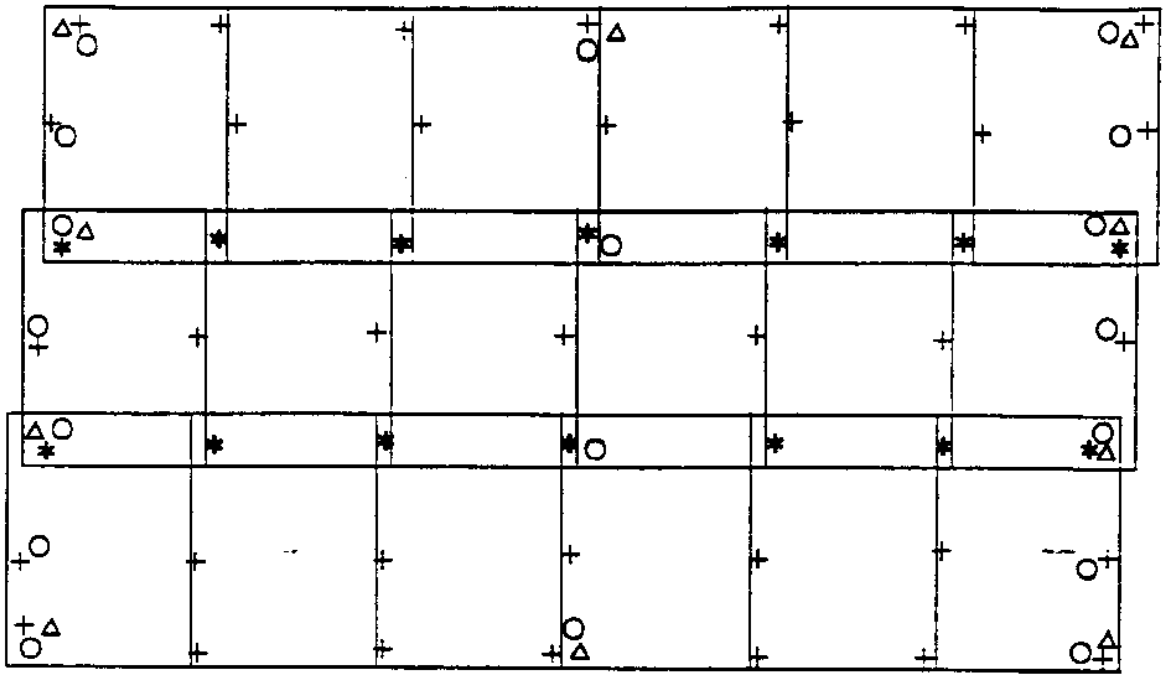
A great advantage of off-line and digital orthophoto production is that updates can usually be performed without having to generate new DEMs. Changes on the earth's surface are usually to planimetric detail, such as buildings and roadway alignments, and not to relief. Changes in planimetric detail can be captured by obtaining new photography, determining the orientation of the camera for each new photo, and using the original DEMs to produce new orthophotos. Complete stereomodels for creating new DEMs need not be formed.

CONTROL REQUIREMENTS

To scale a stereomodel for absolute orientation, a minimum of two horizontal control points (known Xs, Ys) must be available. It is advisable, however, to have three or four horizontal control points to provide redundancy for scaling. The leveling of a stereomodel requires a minimum of three vertical control points (known elevations), with four or five (one in each corner of the model and one in the middle) being desirable for redundancy.

Fortunately, this does not mean that extensive ground surveys must be run all over a project area in order to provide dense geodetic control. A photogrammetric computational method, known as *analytical aerotriangulation* can be used to extend both horizontal and vertical control from selected points around the project perimeter and within its interior. Figure 19-5 depicts a block of photos with a typical control configuration for a project area. Horizontal and vertical control points should appear every 4-7 photos around the perimeter and additional vertical control points should appear every 4-7 photos in each strip in the interior.

Typically some field work is required to establish geodetic control points in appropriate places even if substantial control already exists. The advent of the Global Positioning System (GPS) has reduced the required time and costs of establishing geodetic control for aerotriangulation.



△ Horizontal control points   + Pass points
○ Vertical control points   ✱ Tie points

Figure 19-5: Example control configuration for a block of photos. (After Wolf (1983))

All geodetic control to be used in aerotriangulation must be marked on the ground prior to the photographic mission. An artificial target (sometimes referred to as a "panel") is centered on each control point. Targets can be painted on pavement or made of plastic or muslin material staked to the ground. White is the most frequently used color.

Two target shapes recommended in the *Manual of Photogrammetry* (ASP 1980) appear in Figure 19-6. The recommended minimum sizes and spacings of the components marked in the figure appear in Table 19-3. These minimum dimensions are adequate for the best measuring equipment and should be perhaps doubled for equipment of lesser quality. Wolf (1983) recommends an image size of 0.03 mm to 0.10 mm for the length of a side of a square central panel.

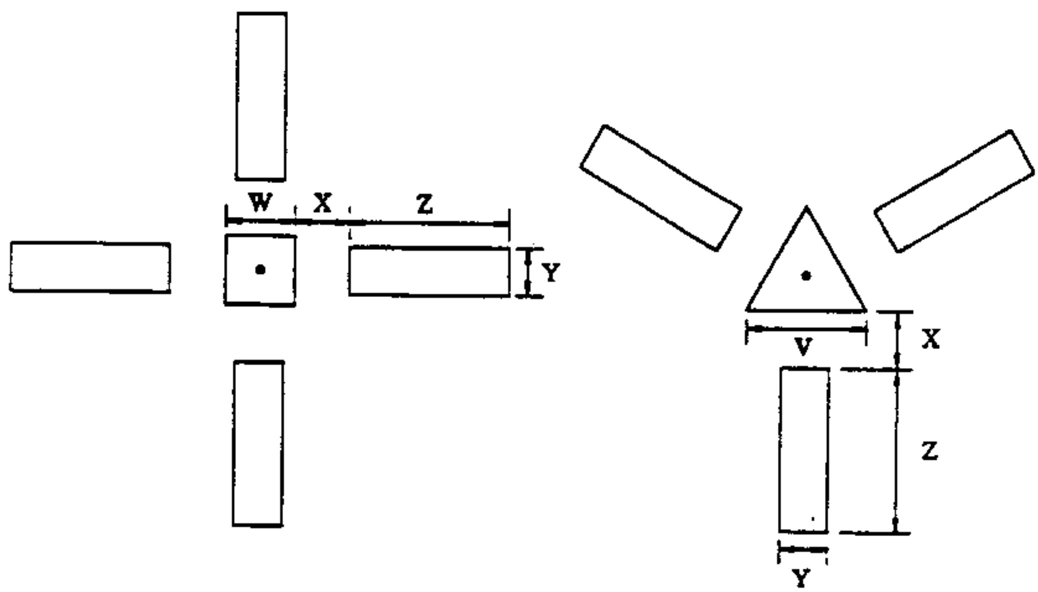


Figure 19-6: Artificial targets. (After ASP, 1980)

Scale of Photography	Dimensions (meters)				
	V	W	X	Y	Z
1:10,000	0.5	0.3	1.3	0.2	0.9
1:20,000	1.1	0.7	2.6	0.4	1.8
1:30,000	1.6	1.0	3.9	0.5	2.7
1:40,000	2.2	1.3	5.2	0.7	3.6
1:50,000	3.2	2.0	7.8	1.1	5.4
1:60,000	3.8	2.3	9.1	1.3	6.3

Table 19-3: Target Sizes (from ASP, 1980)

Figure 19-5 also depicts "pass points" which link consecutive photos in a strip and "tie points" which link adjacent strips. After a flight and in preparation for aerotriangulation, these points are selected and marked with precision equipment that makes tiny holes in the photographic emulsion. Pass points and tie points are selected at sharply defined images such as those of building corners, sidewalk intersections, and bridge abutments. The coordinates of all control points, pass points, and tie points that appear in each photo are measured precisely with a precision of a few micrometers or with sub-pixel precision with digital methods. These image coordinates are then corrected for several systemic errors, including distortion caused by the aerial camera's lens, based on lens calibration data.

Refined image coordinates of all points, ground coordinates and elevations of all geodetic control, estimates for the ground coordinates of all pass points and all tie points, numerical estimates for the orientation of each photograph, and numerical information concerning the aerial camera are then used in the analytical aerotriangulation computations. Among the results are ground coordinates and elevations of the pass points and tie points. The pass points and tie points now supplement the original geodetic control during absolute orientation of the individual stereomodels for mapping.

For topographic mapping, the required accuracies of pass point and tie point ground coordinates and elevations are based on the scale and contour interval of the map to be produced. As a rule of thumb, horizontal coordinates should contain no more than one-half the allowable error in the horizontal coordinates of map features (Wolf 1983). Final elevations of pass points and tie points should be accurate to within one-fifth the contour interval. Of course, the original geodetic control for the aerotriangulation must be more accurate than this.

For pass points and tie points, analytical aerotriangulation commonly produces accuracies of 1/15,000 of the flying height in X and Y and 1/10,000 of the flying height in elevation. A typical flying height for 1:4,800 mapping would be from 10,000 to 15,000 feet, depending upon the instrument used for compilation. This would yield X and Y accuracies of up to about 1 foot and elevation accuracies of up to about 1.5 feet. Higher accuracies from aerotriangulation are possible if specialized procedures are used. There may be benefit in targeting certain key points in the project area, such as section corners whose coordinates are unknown, prior to the aerial photographic mission, so that their coordinates can be determined by including them in the aerotriangulation.

Systems are currently being developed that include GPS receivers mounted in the aircraft along with the aerial camera. These hold promise for accurately determining the coordinates of the perspective center of the lens (airplane position) at the time of each photograph. This will significantly enhance the aerotriangulation process and greatly reduce the need for geodetic control surveys on the ground.

PROJECT PLANNING

The planning of a photogrammetric project requires the knowledge of professionals experienced in all aspects of the work. Once the project deliverables are agreed upon, planning is required for acquiring the aerial photography, developing the necessary ground control, selecting the appropriate photogrammetric instruments and procedures, estimating costs, and scheduling the work (Wolf 1983). These tasks are usually performed by the contractor on a project, with the client sometimes participating in the development of ground control. The client might be able to perform all or parts of the control surveys. In addition, the client may be able to set out the artificial targets (panels) and maintain them until the aerial photography is acquired.

A discussion of flight planning follows in order to provide insight into the process. The discussion includes an example taken after one presented by Wolf (1983). A photographic flight plan must account for the final map scale and contour interval, and equipment being used (particularly the camera and stereoplotter), and also specify the format of the film, the speed of the aircraft, the extent of the project area, the season of the year, the time of day, the weather, and the nature of the features being mapped.

Typically, the weather must be no more than 10 per cent cloudy. "Smooth" air is desirable to prevent unwanted crab and drift of the aircraft. The spring of the year is prime flying time in much of the United States, before trees are leafed out, but after most snow has melted. Late morning through early afternoon, while the sun's altitude is above 30 degrees, is the best time of day. Otherwise, long shadows might obscure detail on the photos.

As with all instruments, the quality of a stereoplotter depends upon its construction and cost. One method of rating the performance of a stereoplotter is by its "C factor" which relates maximum flying height above mean terrain to the maximum contour interval that can be reliably plotted with that photography. An equation form of the relationship is:

$$C \text{ factor} = H / C.I.$$

where H is maximum flying height above mean terrain and C.I. is the required contour interval. C factors range from 800 to about 2,000 (Wolf 1983). Higher quality stereoplotters have higher C factors and, thus, allow greater flying heights. The greater the flying height, the greater the ground coverage of a single photo and of a stereo pair. Therefore, stereoplotters with high C factors minimize the number of models that are required to cover a given project area.

Stereoplotters also have a maximum enlargement ratio between the scale of the aerial photos and the scale of the map to be produced. The best stereoplotters have maximum enlargement ratios of 7-8.

As an example, assume that photography is to be acquired of the rectangular project area in Figure 19-7, having a width, W, of 8 miles and a length, L, of 15 miles. The camera has a nominal 6-inch focal length lens and 9 inch square film format. The stereoplotter has a C factor of 1,800 and a maximum enlargement ratio of 8. The final map is to have a scale of 1:2,400 and a contour interval of 5 feet. The contract specifies that end lap will be at least 60 percent and side lap will be at least 30 percent.

According to the C factor and contour interval, the maximum flying height above mean terrain is

$$H = 1{,}800 \times 5 \text{ ft.} = 9{,}000 \text{ ft.}$$

At this flying height, the photo scale is

$$PS = f / H = 6 \text{ inches} / 9{,}000 \text{ ft.} = 1{:}18{,}000$$

where PS = photo scale and f = focal length of the lens. An eight-times enlargement allows a map of 1:2,250 to be compiled

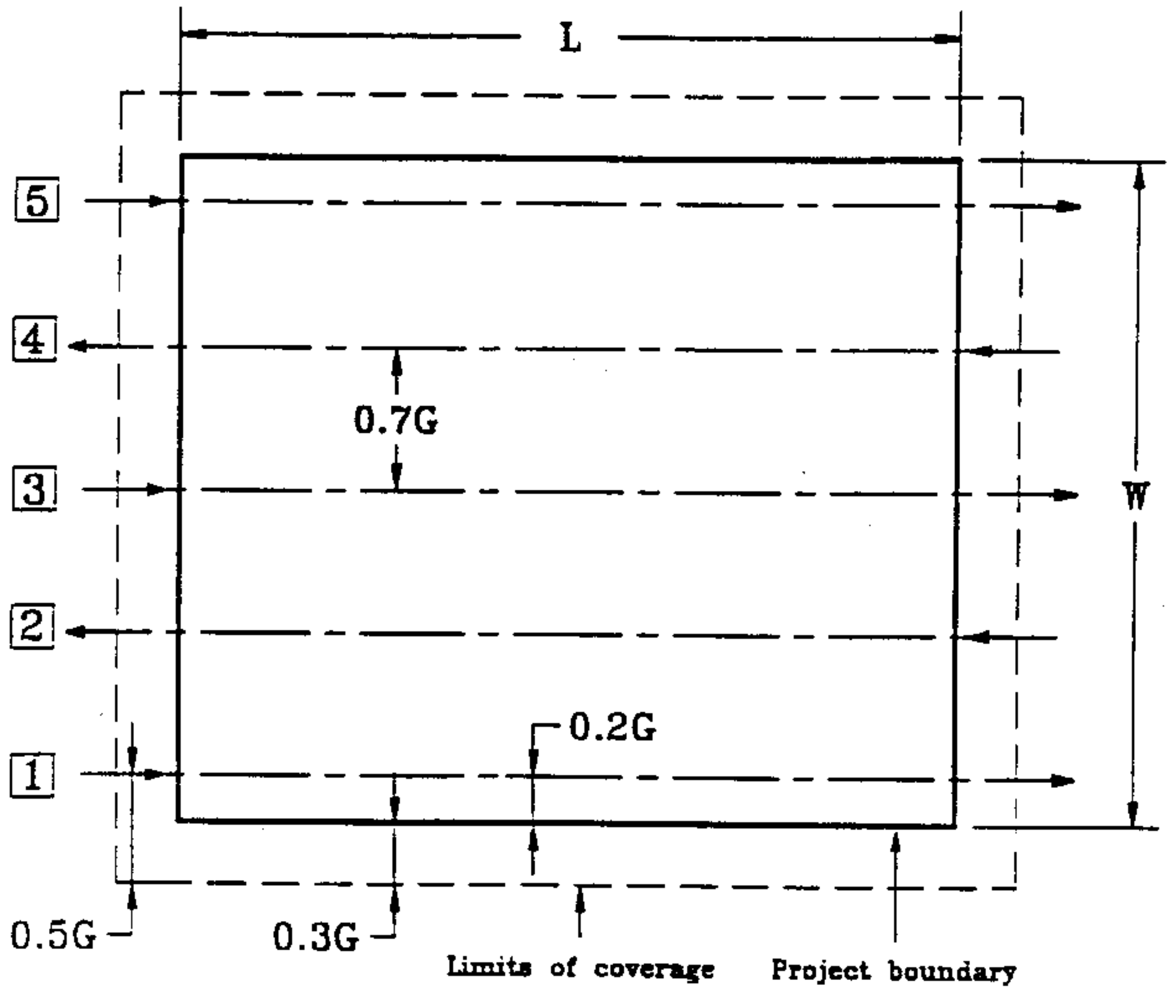


Figure 19-7: Flight layout for hypothetical project area. (After Wolf (1983))

from this photo scale. Therefore, the flying height above mean terrain should be 9,000 ft.

The square, covered on the ground by a single photo, has a side dimension (G in Figure 19-3) of

$$G = 9 \text{ inches} \times 18{,}000 \times 1 \text{ ft.} / 12 \text{ inches} = 13{,}500 \text{ ft.}$$

With a 60% endlap, the forward advance between consecutive photos in a strip is 40% of G (see Figure 19-3)

$$0.4 \times G = 5{,}400 \text{ ft.}$$

The number of photos per strip (with 2 additional at each end of a strip) is

$$\# \text{ photos / strip} = \frac{15 \text{ mi x } 5280 \text{ ft / mi}}{5{,}400 \text{ ft / photo}} + 2 + 2$$
$$= 18.7 \text{ (use 19).}$$

The lateral advance between adjacent strips is (see Figure 19-7)

$$0.7 \text{ x } G = 9{,}450 \text{ ft.}$$

The distance of the first and last flight lines inside the project boundaries is

$$0.2 \text{ x } G = 2{,}700 \text{ ft.}$$

The number of flight lines is

$$\# \text{ flight lines} = 1 + \frac{8 \text{ mi x } 5{,}280 \text{ ft/mi} - 2 \text{ x } 2{,}700 \text{ ft}}{9{,}450 \text{ ft / flight line}}$$
$$= 4.9 \text{ (use 5).}$$

The adjusted spacing between flight lines is

$$\frac{8 \text{ mi x } 5{,}280 \text{ ft/mi} - 2 \text{ x } 2{,}700 \text{ ft}}{4} = 9{,}210 \text{ ft.}$$

The total number of photos is

19 photos per strip x 5 strips = 95 photos.

This information will be included in instructions to the pilot. The pilot will attempt to maintain straight flight lines and constant ground speed by compensating for winds aloft. Most of the diagram in Figure 19-7 will be transferred to an existing small-scale map of the project area. This flight map will be used by the pilot for spotting landmarks along each flight line and keeping the plane on course along the strips.

CONTRACTING FOR TOPOGRAPHIC MAPPING SERVICES

Large-Scale Mapping Guidelines (ASPRS-ACSM 1987) includes sections on contracting and on sample specifications (see Appendix 19-1). The following is a summary of that discussion.

The selection of a contractor for topographic mapping is critical. Two important factors in the evaluation of contract proposals are the availability of photogrammetric plotting equipment and the proposed work plan. Evaluation of proposals for topographic mapping requires a level of expertise that is probably not present in most local government agencies. If necessary, outside experts should be sought to serve as members of a review panel for proposal evaluation.

Proposals should describe the stereoplotter(s), including their C factors. As noted earlier, the higher the C factor, the higher the maximum flying height for a given contour interval, and thus the fewer the number of necessary stereomodels. However, this kind of savings may be partially offset by the contractor's amortization of the more expensive equipment that higher C factors typically require.

Evaluation of the work plan should consider the contractor's ability to perform field surveys, aerotriangulation, map finishing, etc., and to deliver products in digital formats, if desirable. Proposed work plans should include descriptions of the qualifications of the employees who will be assigned to the project; identification of the type of aerial film and camera to be used, including the date of its last calibration; descriptions of the in-house photogrammetric equipment to be used; a description of the procedures and software to be used for aerotriangulation; descriptions of support equipment such as printers, copy cameras, etc.; the photo scale and map compilation scale; descriptions of methods and equipment to be used for ground control surveys, including the numbers and locations of permanent control monuments to be established; materials for map manuscripts, finished maps, and map reproduction; a schedule for completion of the project; description of any work to be subcontracted, including equipment and qualifications of the subcontractor(s); a listing of similar projects completed by the firm; and professional, business, and financial references.

SUMMARY OF SPECIFICATIONS FOR CONTRACTING

When contracting, contract specifications should be included for the following (see Appendix 19-1 for details):

1. Aerial Photography

   The location and size of the project area should be indicated on the flight map, which is an attachment.

   The conditions under which the photography is to be taken. A sky free of clouds and atmospheric haze is suggested. Also, times within 2 hours of local solar noon during the season before leaves have appeared and after snow has left the ground are suggested, as is a sun angle not less than 30 degrees.

Precision aerial cameras and magazines calibrated by the U.S. Geological Survey and currently approved for use on U.S. Geological Survey projects.

Stable-based films such as Cronar or Estar-based films. An emulsion such as Kodak type 2402 is acceptable for black-and-white photography. **The use of color aerial photography is encouraged** as it better supports other uses of the photographs.

A proposed flight plan.

Spacing of photographs. It is suggested that end lap be not less than 55 percent and not more than 65 percent, with an average of 60 percent. Side lap should be not less than 20 percent and not more than 40 percent, with an average of 30 percent. Crab in excess of three degrees might be cause for rejection of a flight line or any portion of a flight line where the crab occurs.

Tilt of the camera from vertical at the instant of exposure should not exceed three degrees nor should the tilt difference exceed five degrees between successive exposures. Average tilt over the project should not exceed one degree.

Flight lines should extend one full photograph beyond the end boundaries. Side boundaries should be covered by at least 25 percent of the photoimage format.

The contractor should propose **the flying height** along with the stereoplotting equipment to be used. Deviation from designed flying height should not exceed five percent low or five percent high.

Reflights should be required if unacceptable coverage results from deviation from the flight plan. Coverage from reflights should overlap accepted coverage by two stereomodels.

Image quality including use of maximum shutter speed, considering aperture and film speed, to minimize image motion. Details on film processing should be included.

Film labeling, including a requirement for consecutively numbered images with the date appearing in each image. The last frame on each flight line should show the time of exposure, the camera focal length, and the flying height above mean terrain.

Details on preparation of a photoindex and/or a labeled mosaic.

The number of contact prints to be delivered and the disposition of aerial negatives.

2. Ground Control Surveys

Horizontal and vertical datums for geodetic control.

The number of horizontal and vertical control points to be established by the contractor and the number by the contractee.

The accuracy and the monumentation for newly-established control points.

Descriptions of how to reach each new control point, field sketches, and markings of control points on photographs.

Field survey procedures for establishing new control points and for tying photo-visible points to control monuments.

Delivery of field survey records, control descriptions, computations, and related materials.

An option, held by the technical officer for the contract, to **check the accuracy and adequacy of the field survey prior to any map compilation work.**

3. Project Design

The number and type of map sheets required to cover the project area.

The map scale and contour interval.

Maximum map sheet size.

Basis for the **map projection.**

Details on map contents, including coordinate grid, marginal data, planimetry (with details on features), contours and spot elevations, and annotation.

Finished scribing or drafting, with details on the media, standards of workmanship, and the nature of map reproductions.

Media of the map manuscripts. Stable polyester with a minimum thickness of 0.004 inches at a scale equal to or larger than the final map scale is suggested.

Map accuracy. See following section of this chapter on topographic mapping standards.

Aerotriangulation, with procedures and equipment to be approved by the technical officer for the contract.

An option, held by the technical officer for the contract, **to inspect the work either in the field or in the contractor's plant at any time.** Inspections should be completed within 60 days after receipt of the maps.

If **orthophotos are required, the method for their preparation.** A tolerance of 0.04 inch on mismatches in the final image is suggested. Reproduction materials for orthophotos should be specified.

If digital maps are required, then in addition to the above considerations, specifications should be included for at least the following:

1. **The delivery media** (disk, tape, telecommunications, CD ROM, etc.).

2. **Physical format of the delivery media** (operating system and software package compatibility).

3. **The data model**, or the general way in which the data are to be described (perhaps by specifying a proprietary file or data base format).

4. **If appropriate, the number of "layers" and the features appearing in each layer.**

5. **The data format.** If a data exchange format is specified, then the input/output code (e.g., ASCII) should also be specified.

6. **Degree to which the data are to be edited** for compilation errors (polygons closed, overshoots and undershoots eliminated, etc.). Tolerances for automated editing procedures ("snap" distance, etc.).

7. **Topological relationships** to be included.

8. **Labeling or identification** scheme for features.

9. **Method for insertion of annotation.**

10. **Symbol tables** to be provided.

11. **Attribute data bases** and their characteristics.

UPDATE CYCLES

Topographic maps should become part of an on-going program to provide current, accurate, spatial information for decision-making. As changes take place in the landscape, topographic map information can become quickly outdated. Periodic updates should be built into the mapping program.

Planimetric detail in built-up urban areas is quite stable, with few significant changes occurring over time. Topographic map updates in these areas might be on an ad hoc basis to respond to major construction and re-development. Changes in the rural landscape occur at a moderate pace. Topographic map updating in rural areas should perhaps be on an 8-10 year cycle. Suburban and urban fringe areas undergo significant changes with rapid development. Topographic maps in these areas might need to be updated every 3-5 years.

As mentioned in the earlier section of this chapter on orthophotographs, if orthophotomaps are used, it might be possible to update them without forming complete stereomodels on stereoplotters. This assumes that a digital elevation model of the terrain has been retained and that no significant changes in relief have occurred.

TOPOGRAPHIC MAPPING STANDARDS

Most contracts for topographic mapping require the work to be done to certain standards, in terms of content and geometric accuracy. For many years, it was routine to specify National Map Accuracy Standards for geometric accuracy. For horizontal accuracy, these standards require that not more than 10 percent of tested points be in error by more than 1/30 inch at publication scale (for larger than 1:20,000) and 1/50 inch at publication scale (for 1:20,000 and smaller) (American Society of Photogrammetry 1980). These limits of accuracy apply to positions of well-defined points only. For vertical accuracy, not more than 10 percent of tested elevations are to be in error by more than one-half the contour interval for all publication scales.

Large-Scale Mapping Guidelines (ASPRS-ACSM 1987) in the section on sample specifications, suggests that at least 90 percent of all well-defined planimetric features should be within 1/40 inch of their true positions and all remaining features should be within 1/20 inch of their true positions. Further, at least 90 percent of all elevations determined from solid-line contours should be accurate within one-half the contour interval and the remaining 10 percent should be accurate within one contour interval. At least 90 percent of spot elevations shown on a map should be accurate within one-fourth the contour interval and the remaining 10 percent should be accurate within one-half the contour interval.

Because of perceived inadequacies in National Map Accuracy Standards, especially as applied to large-scale computerized or digital maps, professional societies and government agencies have been actively preparing new mapping standards over the last few years. In 1988, ACSM published a proposed standard for digital cartographic data which covered definitions, data transfer, data quality, and cartographic features. In 1990, ASPRS published a new geometric accuracy standard for large-scale maps. During 1992, the Spatial Data Transfer Standard (SDTS), developed from the 1988 ACSM work and referring to the 1990 ASPRS standard, was adopted as a Federal Information Processing Standard (FIPS 173).

The 1990 ASPRS geometric horizontal accuracy standard provides specific limiting root-mean-square errors at ground scale for Class 1 maps ranging from 1:50 to 1:20,000 in scale (see Tables 19-4 and 19-5). For vertical accuracy, the limiting root-mean-square error is one-third the indicated contour interval.

Planimetric X or Y Accuracy limiting rms error, feet	Typical Map Scale
0.05	1:60
0.1	1:120
0.2	1:240
0.3	1:360
0.4	1:480
0.5	1:600
1.0	1:1,200
2.0	1:2,400
4.0	1:4,800
5.0	1:6,000
8.0	1:9,600
10.0	1:12,000
16.7	1:20,000

Table 19-4: Limiting RMS Errors (feet) in X or Y (from ASPRS (1990))

Planimetric X or Y Accuracy limiting rms error, meters	Typical Map Scale
0.0125	1:50
0.025	1:100
0.050	1:200
0.125	1:500
0.25	1:1,000
0.50	1:2,000
1.00	1:4,000
1:25	1:5,000
2.50	1:10,000
5.00	1:20,000

Table 19-5: Limiting RMS Errors (Meters) in X or Y (from ASPRS (1990))

Similar to National Map Accuracy Standards, tests are to be applied only to well-defined points. However, a minimum of 20 well-distributed check points are required. Root-mean-square errors are derived from differences in positions of check points as they appear on the maps and as they are determined by precise ground survey.

PARCEL MAPPING

In the United States, typical parcel maps depict land ownership units for taxation purposes. Very often the original purpose of such maps was to provide a graphical index for real property tax records. However, because of the great need for land ownership information in the operation of local government, tax parcel maps are often used for many more purposes, such as planning, zoning, assessment, and permit granting. However, it is important to note that tax parcel maps do not necessarily have a direct correspondence to deeds, titles, easements, and other records of land rights.

Figure 19-8 is extracted from a modern, accurate parcel map prepared by the Southeastern Wisconsin Regional Planning Commission. This map was derived from legal descriptions and survey records, referenced to section and quarter section corners whose state plane coordinates had been determined by ties to the National Geodetic Reference System (NGRS). The parcel map in Figure 19-8 can be overlaid with the topographic map in Figure 19-1 which is also referenced to the NGRS.

Parcel mapping is a complex process that involves establishing a base or framework to begin with and then fitting together parcel information in a way that resembles the working of a jigsaw puzzle. However, the sizes and shapes of the puzzle pieces must be derived from diverse, and sometimes inconsistent, sources such as written legal descriptions in deeds, wills, mortgages, and court records; graphic records such as survey plats of varying scale, age, and quality; and, perhaps, aerial photos and other maps. Individual source documents might provide information on individual parcels or might describe any number of adjoining parcels, such as those in a subdivision. Even if the sizes and shapes of the individual puzzle pieces can be determined, their precise locations often cannot. It is also possible for neighboring parcels to be described in ways that cause overlaps or gaps between their boundaries.

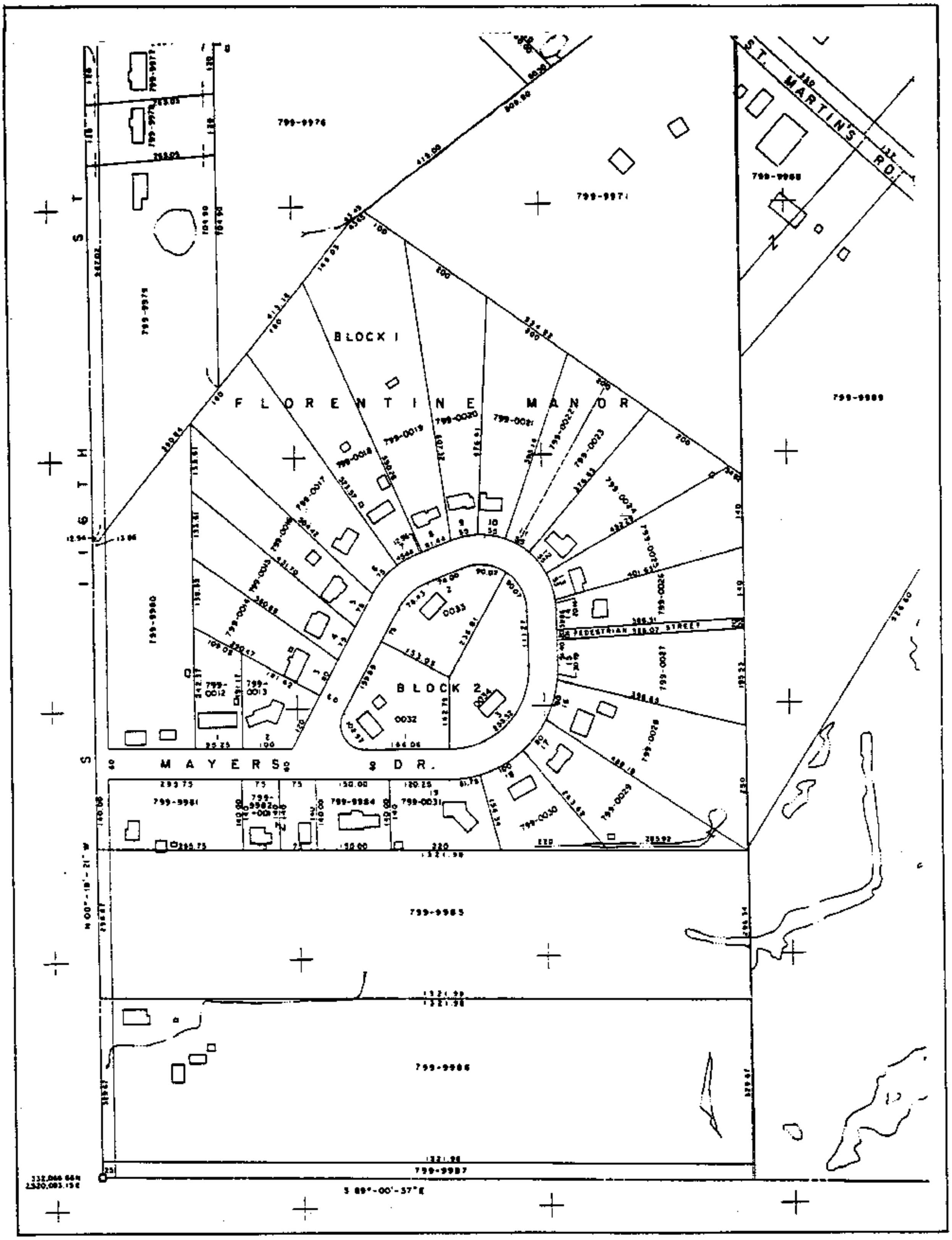


Figure 19-8: A portion of a typical cadastral map in southeastern Wisconsin (courtesy of SEWRPC).

Accurate parcel mapping is further confounded by the general lack of a sound geometric framework to begin with. In much of the United States, the legal reference system for land parcels is the Public Land Survey System (PLSS) (see Chapter 6). Unless mathematically based surveys have been made of the PLSS, the true sizes and shapes of sections of land will only roughly be known. The descriptions and survey records that define the locations, sizes, and shapes of individual parcels (the puzzle pieces) are referenced to these sections. Moreover, even if the true sizes and shapes of PLSS sections are known, parcel maps cannot be integrated with other kind of maps unless they have been tied to the NGRS.

In metes and bounds states, the reference framework for describing parcels is usually ad hoc and consists of a collection of natural features (streams and shorelines, ridgelines, rock outcrops, individual trees, etc.) and cultural features (roads, fences, boundaries of adjoining parcels, etc.). Before parcels can be accurately mapped in such areas, the locations of key features in the parcel reference framework must be determined by control survey methods or by planimetric mapping.

For these reasons and others, the cadastral cartographers, who prepared most of our original tax parcel maps, were aware of the maps' shortcomings. Many users of those maps are not similarly aware. In many jurisdictions, the best available parcel maps might have been originally drafted 50 or more years ago and are taken for granted today. Even though inaccurate, such maps might adequately serve some role, such as indexing and large area planning, in a land information system. But agencies seeking to modernize, make improvements, or develop multipurpose systems should carefully evaluate their parcel mapping situations. This is especially true for proposed computerized systems, where such maps can be automatically integrated with other information and problems with their quality might be masked by the technology.

PLANNING THE PARCEL MAPPING PROGRAM

The success of a parcel mapping program often depends upon the breadth and depth of its planning. Plans for parcel mapping must address institutional arrangements, technical details, and management considerations.

Participants in the program and their various roles must be decided upon. It is necessary to identify information sources and information flows for both development and maintenance of the parcel maps. It is also necessary at an early stage to decide if the mapping will be done in-house or by contract.

The reference framework for mapping individual parcels must be selected. In some cases, it will need to be constructed in the field. Standards for scale, sheet size, content, and accuracy should be developed. Source documents to be collected must be identified. General and detailed procedures for mapping should be decided upon. General procedures address the level of technology to be used (i.e., manual drafting, manual drafting followed by digitizing or scanning, or automated map construction). Detailed procedures include decision rules for resolving ambiguities and conflicts in parcel locations and standards for annotation. Methods for tracking lineages of individual parcels should be developed. A parcel identification scheme must be selected.

A detailed schedule should be developed that includes milestones for the completion of individual tasks. Scheduling should reflect priorities for completion, perhaps based upon the extent of development or major construction in certain areas. Methods for keeping the parcel map current must be developed and implemented before the mapping is completed.

GENERAL APPROACH

Manual drafting of parcel maps typically results in final inked maps on a stable-based medium. Establishment of the mapping framework and the placing of individual parcels is usually done on worksheets using standard drafting techniques and interpretation of source documents and base map detail. The final map is developed as an overlay from the worksheets.

If the desired end result is a digital parcel map, compilation by coordinate geometry might be considered. Typically, successive parcel corner coordinates are computed from bearings and distances that appear on survey plats and in legal descriptions. Other than having the maps immediately in digital form, a further advantage of this method is that lineage information on source documents and decision rules can be directly associated with each parcel as attributes (URISA-IAAO 1992).

Selection of appropriate software to support this method is critical. Parcels can be described in many ways that do not explicitly call for bearings and distances on every boundary. Moreover, once a parcel's size and shape are determined, it must be placed within the mapping framework. This operation can involve translation, rotation, scaling, and perhaps visual fitting to underlying base map features. Software to support fully automated parcel mapping must be able to manage a wide variety of parcel descriptions and perform a significant number of mapping operations.

A further consideration when using fully automated techniques is that more detailed decision rules for resolving conflicts might have to be developed. This is because the computations will include errors that are inherent in recorded survey measurements. These errors (even small ones) will lead to coordinate misclosures that might be obscured by the line weight on a manually drafted map.

A third alternative is to draft the parcel maps manually and then digitize or scan them to convert to digital form (SEWRPC 1985). This method avoids some of the above problems. Of course, it does not capture the full precision of recorded survey measurements, but this precision is unnecessary for many purposes.

PARCEL MAP SCALE AND CONTENT

Chapter 13 contains a discussion of the contents of parcel maps, including not only map features but also considerations for the treatment of various real property rights such as easements, subsurface and air rights, and condominiums.

Concerning scale, the recommendations of the National Research Council (1983) appear in Table 19-6. The *Standard on Cadastral Maps and Parcel Identifiers* (1988) of the International Association of Assessing Officers coincides with the NRC recommendation for scales in urban and suburban areas, but includes both 1:4,800 and 1:9,600 in rural areas.

Minimum parcel size is the primary consideration in selecting parcel map scale. Moreover, the scales of the parcel map and the underlying base map must be the same if the base map is to be used as a reference when constructing the parcel map or if the base map and parcel map are to be integrated in a digital environment. For this reason, minimum parcel size should be one of the primary criteria for selecting the scale of the base map (see previous section of this chapter, "Matching Scale to Use").

Type of Area	Typical Lot Frontage	Comparable Map Scale (Customary)	Comparable Map Scale (Metric)
Urban	15 - 40 ft	1:600	1:500
Urban	50 - 90 ft	1:1,200	1:1,000
Suburban	100 - 180 ft.	1:2,400	1:2,000; 1:2,500
Rural	200 or more ft.	1:4,800	1:2,000; 1:5,000

Table 19-6: Suggested Parcel Map Scales (from NRC (1983))

SOURCE DOCUMENTS

Crane et al. (1989) lists 25 local government offices that might manage source documents necessary for parcel mapping. Of these, the most critical are:

1. Register of Deeds (for deeds, mortgages, easements, and other title documents);

2. Surveyor (for subdivision plats, re-survey plats, survey notes, section corner ties, geodetic control information, etc.);

3. Transportation, Public Works, and Engineering (for rights-of-way and other public easements);

4. Administration (for jurisdictional boundaries and publically-owned lands);

5. Parks and Recreation (for park boundaries, greenways, etc.);

6. Court Administration (for decisions affecting parcel boundaries and titles); and

7. Utilities (for easements).

An identification system and filing system for all source documents must be developed. Appropriate organization of source documents facilitates not only the mapping process, but also the development of lineage information on each parcel.

ESTABLISHING THE FRAMEWORK

The framework for parcel mapping establishes a link to a ground coordinate system that is common for all maps in a multipurpose land information system. This linkage has two forms: 1) direct ties by ground surveys between the National Geodetic Reference System (NGRS) and the legal referencing system for parcels and 2) the planimetric detail of the base map (some source documents will contain extensive references to natural and cultural features of the landscape).

Where the PLSS has been directly tied to the NGRS by ground surveys or aerotriangulation, a significant component of the framework will be accurately plotted section and quarter-section corners and the lines that form section and quarter-section boundaries. The presence of precise coordinates for PLSS corners does not alleviate the need for a base map. Source documents often contain references to streams, lakes, fencelines, and other features that require a base map in order to plot parcel boundaries.

Where there are no direct ties between the PLSS and the NGRS, it might be possible to plot PLSS corners with acceptable accuracy by referring to their tie sheets. These documents, typically developed during the re-monumentation of corners (see Chapter 6), show the locations of PLSS corners by measured distances to well-defined surrounding features such as the corners of buildings and the intersections of sidewalks, or by offsets from linear features such as fencelines, pavement centerlines, and the backs of curbs. Where a sufficient number of these features appear on the base map, the positions of PLSS corners can be plotted from the distances and offsets.

In metes and bounds states, the base map plays an even more definitive role. Here, legal descriptions for individual parcels will refer to landmarks, artificial monuments established by surveyors, adjoining boundaries, roadways, fencelines, and the like. Without an accurate base map, parcel boundaries cannot be plotted with any degree of certainty.

MAPPING THE BOUNDARIES

At least the following kinds of legal descriptions for parcels can be encountered during interpretation of source documents (Brown et al. 1986):

1. Reference to the PLSS such as "the northwest quarter of Section 10." There are specific rules, which change from time to time and place to place, for establishing boundaries of aliquot parts of the PLSS.

2. Perimeter descriptions, referring to measurements (e.g., bearings and distances), monuments, or adjoining owners, or their combinations and including "metes and bounds."

3. Strip descriptions and stationing for rights-of-way and other linear easements. The centerline might be described by metes and bounds.

4. Reference to a map or plat such as "Lot 1, Block 2, Wildwood Bluff Estates."

5. Reference to a dividing line such as "all of Section 10 lying southeasterly of Smith Road."

6. Reference to a distance such as "the westerly 45 feet of lot 6."

7. Reference to a proportion such as "the south one-half of Lot 6." NOTE: This conveys one-half the area of Lot 6, but "the northwest quarter of Section 10" does not convey one quarter of the area of Section 10. Rules for the subdivision of sections of the PLSS apply in the latter case.

8. By exception such as "Lot 6 except the easterly 30 feet thereof."

9. By area such as "the south one-half acre of Lot 3."

10. Combinations of the above.

During interpretation of source documents and plotting of boundaries, conflicts and ambiguities will almost certainly arise. They can result from any of a number of causes, including poor wording, incorrect assumptions, lack of a clear basis for directions, transcription mistakes, errors and mistakes in measurements, misinterpretation, and so forth. Conflicts and ambiguities can be internal, such that the size and shape of a parcel cannot be determined, or external, such that a parcel's location cannot be determined. In fact, there is an entire body of law, referred to in Chapter 13, that establishes the order of importance of conflicting title elements for locating parcel boundaries on the ground.

For the purpose of parcel mapping (without a comprehensive cadastral survey and adjudication), the National Research Council (1983) suggests the following weighting of evidence by broad categories in descending order:

1. Natural boundaries as plotted on the base map;
2. Geodetically referenced cadastral surveys;
3. Monument referenced cadastral surveys;
4. Physical evidence of original surveys (such as old rural fences);
5. Deed descriptions, referenced to natural boundaries or survey measurements; and
6. Deed descriptions, referenced to adjoining parcels.

Highly weighted information should be plotted first and held fixed, while lower-weighted information is fitted to it.

The following are among the guidelines offered by Crane et al. (1989) for resolving problems with interpretation of deed descriptions during parcel mapping (elaborations are added):

1. If there is sufficient language to identify the parcel on the ground, the description is a valid one. This is true whether or not the parcel can be plotted on a map, based only upon its current description. A description with conflicts and ambiguities is valid as long as the boundaries can be located by a surveyor.

2. Indefinite boundaries do not invalidate definite boundaries. Missing information can sometimes be derived from given information.

3. Boundaries or monuments are paramount to distances or angles. "N 10 30 E, 100 feet to an iron pin" means "go

to the iron pin whether or not it is 100 feet away or on a bearing of N 10 30 E."

4. A survey map or plat is paramount to other inconsistent particulars if it appears that the parties acted with reference to the map. Within a single legal description a parcel can be described both as a lot in a subdivision and by metes and bounds. If the metes and bounds description conflicts with the subdivision plat, the plat controls.

5. When a road or non-navigable stream is the boundary in a deed, title is conveyed to the thread of the stream or the centerline of the road right-of-way (unless title is held by a party other than the grantor).

6. When tide water is the boundary in a deed, title is conveyed to the mean high tide line.

7. With a navigable lake or stream, title is conveyed to the edge at the normal low water mark.

8. Generalities yield to precise language. A description reading "the south half of Lot 7, containing 1 acre more or less" conveys the south half of Lot 7, whether or not it contains 1 acre.

9. Statements of acreage yield, unless there is language indicating that only a specific quantity of land was intended to be conveyed. "The northwest quarter of Section 10, containing 160 acres" conveys the northwest quarter of Section 10, whether or not it contains 160 acres. "The south 140 acres of the northwest quarter of Section 10" conveys 140 acres, as long as the northwest quarter of Section 10 contains at least 140 acres.

10. If there is conflict between a numeral and a spelled number, the spelled number prevails.

11. Maps or plats that are not explicitly referred to in a description can be used only as guides.

12. General compass terms such as "northerly" or "westerly," where there is no other reference, must be construed to

mean "north" or "west." "Due north" should be interpreted as "astronomical north."

In some cases, it may not be possible to plot parcel boundaries without going to the field to observe lines of possession and other evidence. Some states have statutory provisions for requiring surveys to be done if parcel boundaries cannot be mapped for assessment purposes.

In any case, conventions should be adopted for the treatment of conflicts in the descriptions of neighboring parcels. Such conflicts can lead to gaps, where no owner is identified, or to overlaps, where more than one owner is identified.

As a parcel is mapped, certain information should be recorded including the volume and page numbers or recordation references to pertinent source documents; the owner's and taxpayer's names and addresses; the parcel's location by street address or house number; the parcel's tax assessment description; the original Section, Township, Range, subdivision name, and lot and block numbers (IAAO 1988); and the decision rules applied during mapping of the parcel, if appropriate. If it has been decided to do so, the parcel's area should be calculated and recorded and appropriate dimensions should be added to the map. These latter tasks require minimal effort if the map is being constructed digitally.

PARCEL IDENTIFIERS

Before parcel mapping is complete, unique identifiers must be assigned to each parcel. Parcel identifiers can serve a number of purposes. At a minimum, they provide linkages between the parcel map and the tax role (or the attribute database). The *Standard on Cadastral Maps and Identifiers* (IAAO 1988) discusses three forms of parcel identifiers: 1) location identifiers, 2) name-related identifiers, and 3) alphanumeric identifiers.

A parcel's location is inherent in a location identifier. Identification schemes can be based upon map sheet numbers. Here, a parcel ID would usually contain three parts: 1) the map sheet number, 2) a block number on the map, and 3) a unique number within the block. They can also be based on geographic coordinate systems. Here, the parcel ID consists of the coordinates of a single point, usually the parcel centroid. Finally, they can be based upon the PLSS. Here, the parcel ID includes

Township, Range, and Section numbers, and numbers for the quarter section and potentially the quarter quarter section, plus a unique number for the parcel inside the quarter section or quarter quarter section. The character fields for map-sheet-based and PLSS-based IDs should account for the highest number expected to be assigned to any parcel created in the future (see the next section of this chapter on parcel map maintenance).

A name-related identifier uses the names of individuals claiming an interest in a parcel. An alphanumeric identifier is often an arbitrary number associated with a parcel such as the sequential number assigned in a tract index.

The desirable characteristics of a parcel identifier include 1) uniqueness (a one-to-one relationship between a parcel and its identifier), 2) permanence (a parcel's ID should change only if its boundaries change and a new parcel is created), 3) simplicity (IDs should be easy to understand and use), 4) ease of maintenance (changes should be easily accommodated), 5) flexibility (parcel IDs should be capable of serving a number of uses), and 6) reference to geographic location (this simplifies the handling of property records). Of these, uniqueness is most important in order to prevent chaos in the records system. Further discussion of parcel identification systems is contained in Chapters 10 and 13.

PARCEL MAP MAINTENANCE

Unlike topographic maps, parcel maps can quickly become outdated for many reasons. Parcels can be consolidated and new land divisions can take place. Also, existing parcels can undergo re-surveys that furnish new information concerning boundaries. Transactions that cause changes in parcel maps occur on an ad hoc basis as various documents are presented for recording.

The National Research Council (1983) recommended that parcel map updates be scheduled so that changes are shown no later than two weeks after they come into existence. If the Register of Deeds uses maps to display parcel numbers for indexing and land title records, the recommended maximum update delay is one week. Such a program requires close coordination among those offices mentioned in the previous section on source documents and the parcel mapping office. A robust system for document routing and tracking must be included.

In practice, daily changes are often made on worksheets and then posted to the master parcel map on a frequent, periodic basis. This process can be implemented in a digital environment with daily changes being made to a working copy of the master parcel database. In any case, a schedule for archiving copies of the master parcel map should be developed if it is desirable to keep historic records of the patterns of land ownership.

Identifiers must be assigned to all new parcels. Location-based identification systems provide straightforward means for deriving new identifiers. Coordinate-based identifiers are developed directly from the centroid coordinates of each new parcel. Map-sheet-based and PLSS-based identifiers usually end with numbers assigned sequentially to the individual parcels in the smallest geographic unit of the system, be it a map sheet block or a quarter quarter section. In these systems, the ID of a new parcel is typically one number higher than the highest existing number.

Identifiers should be retired for parcels that cease to exist because of new land divisions. The original parcel remains an historic entity and indexes that identify it should be included in the records system unless provided otherwise by statute (NRC 1983).

Updates to a parcel map should trigger corresponding updates to lineage information and other associated records such as parcel areas, assessment descriptions, etc. Changes in a parcel's boundary information resulting from a re-survey cause changes in the neighboring parcels' boundary information and lineages.

The maintenance program should include provisions for making the updated parcel map and associated records available to users. Copies of the current master map might be made periodically and distributed to the user community.

Parcel map maintenance is typically an in-house function even though the initial mapping project might have been contracted (see "Summary of Specifications for Contracting" and Appendix 19-2). In some cases it might be appropriate to contract for maintenance also. All maintenance of the parcel map should be performed to the specifications of the initial mapping project (Crane et al. 1989).

Parcel map maintenance programs should include plans for re-mapping at larger scales in areas of rapid development and growth

(IAAO 1988). The National Research Council (1983) suggested that a strategy for incremental improvement of parcel maps be built into the maintenance program. That is, in order to avoid the high cost of a comprehensive cadastral survey, initial parcel mapping can be done using current source documents, whatever their quality might be. The maps are then refined over time, through the maintenance program, as re-surveys of existing parcels and surveys of new land divisions provide improved information on parcel boundaries. Improved information results from better technology, improved standards, and more readily accessible geodetic control.

PARCEL MAPPING STANDARDS

Much of the *Standard on Cadastral Maps and Parcel Identifiers* (IAAO 1988) has been previously cited in this guidebook. A brief summary of the standard is provided below.

The first two sections of the standard define its scope and provide an introduction. The third section provides an overview of a basic mapping system with brief discussions of base maps, parcel maps, parcel identifiers, indexes to source documents, a small scale map index to individual parcel map sheets, facilities and equipment, staff and training, and production and maintenance.

The fourth section, on map content, describes basic information that should appear on parcel maps and supplemental information that should be included in overlays. The description of map contents in the standard is cited in Chapter 13 of this guidebook.

The fifth section, on the essentials of design, discusses map sheet sizes, scales (as discussed earlier in this chapter), map materials, symbols, line work, lettering, and map layouts. The sixth section, on preparation for a mapping program, discusses program management, contracting for mapping services, technical specifications (see Appendix 19-2 of this chapter), evaluating mapping firms, and requests for proposals and contractor selection.

The seventh section, on map preparation, maintenance, and security, has subsections on the use of base maps and rectified aerial photos, source documents and field research, and maintenance considerations. The eighth section, on digital mapping and interactive graphics, advocates the use of digital systems for jurisdictions developing new mapping programs. It discusses processes to be automated, system selection, and cost.

The ninth section, on parcel identification systems, describes the kinds of parcel identifiers and the desirable characteristics of parcel IDs as discussed earlier in this chapter.

SUMMARY OF SPECIFICATIONS FOR CONTRACTING

Appendix 19-2 of this guidebook, on sample contract specifications for parcel mapping, is taken from the *Standard on Cadastral Maps and Parcel Identifiers* (IAAO 1988). The following is a summary of those sample specifications.

1. **Source Documents**

   At the county level, source documents should be sought at the Offices of the Register of Deeds, Probate Court, Appraiser, County Clerk, and any other state or county office that has recorded information relating to political subdivision boundaries.

   Reasonable attempts to locate other mapping aids should be made. The aids include original township plats and surveyor's notes, right-of-way acquisition surveys, 1:24,000 USGS topographic maps, and railroad and utility right-of-way plans and easements.

2. **Work Index Card Preparation**

   Information to be recorded for each parcel includes taxing district name, owner's and taxpayer's names, owner's and taxpayer's mailing addresses, plat number (if any), parcel's street address, section, township, and range, subdivision name, lot, and block numbers, acreage, assessment description, recordation reference, and any other information in the assessment records that would facilitate the parcel mapping program.

   The physical record must contain additional space for such things as the final parcel ID, change of mailing address, updated owner names, notes, etc.

3. **Layout and Design**

   Right-of-ways and easements, PLSS lines and corners, utility right-of-ways, and recorded surveys and subdivision plats shall be made to fit physical and cultural features as often as possible.

   Adjacent sheets must be edge-matched on all sides.

   A small-scale county index map must be prepared.

   All recorded subdivisions shall be listed.

4. **Preliminary Parcel Map Compilation**

   A definition of "parcel" is provided.

   Conditions for splitting contiguous ownership into separate parcels and consolidating adjacent tracts under one owner into a single parcel are specified.

   Treatment of mineral rights and condominiums is specified.

   Plotting shall be carried out in accordance with existing source maps, assessment record descriptions, recorded surveys and plats, and vesting instrument descriptions.

   If the existing assessment description is not adequate for plotting, a new assessment description shall be written.

   Examples are given of appropriate technique and notation for assessment descriptions.

   New assessment descriptions are required for splits and consolidations.

   Field interviews are specified for parcels that cannot otherwise be plotted.

   Detailed specifications are given for the line work and annotation that are to appear.

5. **Area Calculations**

   Methods for determining areas are specified.

   Tolerances are given for discrepancies between computed areas and those currently appearing on the tax rolls. If tolerances are not met, then both areas are to appear on the map.

6. **Dimensions**

   Methods for determining dimensions and the conditions under which dimensions are to appear on the map are specified.

7. **Permanent Map and Parcel Numbering System**

   Detailed specifications are given for the numbering of map sheets and parcels.

   The specified map numbering system depends on the map scale and locates each map sheet within the county according to the PLSS.

   The specified parcel numbering system is map-sheet based (this makes it also PLSS-based). A counterclockwise scheme is described for numbering parcels within a map sheet's smallest geographical unit.

   Examples of map sheet numbers and parcel numbers are given.

   Schemes for parcel numbers of future splits, condominiums, leaseholds, and mineral rights are specified. An ownership code for the nature of title is specified.

8. **Field Edits, Errata Lists, and Conflicting Ownerships**

   Field edits for properties not in the assessment records are required.

   Each listing on the tax roll shall be verified.

   Lists shall be prepared of all properties not on the tax roll, all doubly assessed properties, and all parcels on the tax roll that cannot be located or reconciled on the parcel maps.

9. **Title Block and Legend**

   Information and detail to appear in the title block of each map is specified.

10. **Final Map Drafting**

   Final map manuscript material and sheet size are specified.

   A glossary of terms and abbreviations to be used on the maps is given.

   Standards for line weight, labelling, drafting style, and drafting quality are given by example.

   Specifications are provided for placement of annotation for parcel numbers, original lot numbers, block numbers, names of landmarks, acreage, and dimensions.

   Treatment is specified for subdivision boundary ticks, land hooks, "see" notes, notation for conflicts, and subdivision names.

11. **Ownership Listing**

   The contractor is required to furnish a standard data processing tape containing an alphabetical listing of the property owners' names and addresses and associated legal descriptions.

12. **Parcel Map Maintenance**

   The contractor is required to maintain the parcel maps up to a certain number of days before final delivery.

   The county is required to provide copies of new title instruments, maps, plats, right-of-way plans, property transfers, subdivisions, consolidations, street or alley closings, annexations, etc.

   The contractor is required to provide a register of maintenance for all items received during the maintenance period.

13. **Edit and Inspection**

    The contractor, county, and state shall continuously edit and inspect all deliverables until the project has been completed.

    Provision is made for correction of errors.

14. **Inspection and Approval by the County**

    Upon delivery, a complete and thorough review will be made of the quality, quantity, completeness, accuracy, and neatness of all items.

    Provision is made for correction of errors.

SUMMARY

This chapter provides an introduction to the basic methods of topographic and parcel mapping. The discussion of photogrammetric mapping included aerial photography, mapping cameras, stereoplotting, ground control requirements, aerotriangulation, and orthophotos. Our discussion of parcel mapping included alternative approaches, source documents, establishing a mapping framework, plotting of boundaries, dealing with ambiguities and conflicts, and assigning parcel identifiers.

For both topographic and parcel mapping, appropriate scales for the maps, the importance of project planning, and map maintenance strategies were discussed. Emphasis was placed upon mapping standards and specifications for contracting.

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APPENDIX 19-1

Sample Contract Specifications for Topographic Mapping

Part III of Large-Scale Mapping Guidelines (ASPRS-ACSM (1987))

PART III
SAMPLE CONTRACT SPECIFICATIONS

Sample Specifications	Comments
AERIAL PHOTOGRAPHY	
1. Project area	
The location and size of the project area are indicated on the attached map.	Considerable care should be taken in defining the area to be mapped because some problems do not stop at the city limits. For example, drainage from outside the area of primary interest can have so great an effect that coverage should be extended to include the sources of drainage. Moreover, aerial photographs are valuable and highly useful in themselves; and it may be desirable to extend the coverage well beyond the area that will actually be mapped. The additional cost of extra coverage is usually nominal.
2. Conditions	
The contractor shall take vertical aerial photographs, free of clouds, cloud shadows, and atmospheric haze, between 10 a.m. and 2 p.m. during the specified season. When urban areas are photographed, the sun angle must not be less than 30°.	The best time to take aerial photographs is in the spring (usually March or April, or earlier in southern areas) after snow has left the ground and before leaves appear. The next best time is in the fall before snow appears and after the leaves are off the trees, although this photographic season is much shorter than the spring season and the sun angle may be less desirable. If at all possible, a contract should be awarded in January or February so that the contractor can take advantage of the best photographic period and also avoid delay in other work on the project.

Sample Specifications	Comments
3. Aerial camera Only precision aerial cameras and magazines which have been calibrated by the U.S. Geological Survey camera calibration laboratory and currently approved for U.S. Geological Survey projects are to be used. The calibration of the camera shall include the magazine matched to it and only that combination of camera cone and magazine shall be used to take the photographs.	The simplest and best way to assure obtaining high-quality photographs is to specify a camera that has been tested and is currently approved for mapping by the U.S. Geological Survey, which maintains the only official civilian camera calibration laboratory in the Federal Government.
4. Film The film must be scale-stable, such as the Cronar or Estar-based films, must not have passed the suggested expiration date, and must have been stored in accordance with the manufacturer's instructions. An emulsion such as Kodak type 2402 is acceptable for black-and-white photography.	The use of color aerial photographs for large-scale mapping is increasing and should be encouraged if compatible with the contractor's equipment and operations. It is particularly desirable for mapping which requires the location of undergound utilities, as such appurtenances as manholes and catch basins show up more clearly in color.
5. Flight plan With any proposal, the contractor shall submit a plan showing proposed flight lines designed to acquire the photographic coverage specified herein.	
6. Spacing of photographs Overlapping photographs in each flight line shall provide full stereoscopic coverage of the area to be mapped. Endlap (in the line of flight) shall not be less than 55 percent, nor more than 65 percent, and shall average approximately 60 percent. Sidelap shall not be less than 20 percent, no more than 40 percent, and shall average approximately 30 percent. Crab in excess of 3° may be cause for rejection of a flight line or any portion thereof in which the crab occurs.	

Sample Specifications | Comments

7. Tilt

Tilt of the camera from verticality at the instant of exposure shall not exceed 3° nor shall it exceed 5° between successive exposure stations. Average tilt over the project shall not exceed 1°.

8. Boundaries

All flight lines shall extend one full photograph beyond each end boundary, and all side boundaries shall be covered by a minimum of 25 percent of the photoimage format, if practical.

9. Flight height

The contractor shall propose the flight height or negative scale and stereoplotting equipment to be used. The technical officer for the contract shall have the right to reject the proposed scale if, in his opinion, the scale is not suitable for meeting the required accuracy with the particular stereoplotting equipment stipulated in the proposal. Deviation from designed flight height shall not exceed 5 percent low or 5 percent high.

10. Reflights

Unacceptable coverage resulting from deviation from the flight plan shall be corrected at the contractor's expense, with reflight coverage overlapping accepted coverage by two stereomodels. The same camera and magazine used on the original flights shall be used on the reflights.

Sample Specifications	Comments
11. Image quality	
Maximum shutter speed, considering aperture and film speed, shall be used to minimize image motion. The film shall be free of scratches, electrostatic marks, and other blemishes. It shall be exposed and processed with a density range of 1.0 ± 0.2 as measured in the neat model areas of each roll, with minimum densities of 0.40 ± 0.1 above base fog. Density measurements shall be made on a calibrated densitometer with a 0–3.0 range. Base fog shall not exceed 0.15. All negative and fiducial-mark images shall be clear and sharp.	
12. Film labeling	
Each negative shall be clearly labeled on the north edge for north–south flights and one the west edge for eastwest flights. The labels shall include the date at the left, the roll and frame numbers in the center, and a project symbol or identifying name at the right. All negatives shall be numbered consecutively. Final frames on each flight line shall show the time of exposure, the camera focal length, and the flying height above mean ground level.	Details of film labeling can, of course, be tailored to the specific project.
13. Photoindex	
The contractor shall prepare a photoindex by stapling together an assembly of contact prints, trimmed to the image. The prints shall be placed so that corresponding images overlap and all photograph numbers are visible. The assembly shall be photocopied at a specified scale on a sheet tailored to the size and shape of the area. The index shall include title information identifying the area, name of contractor, name of contracting authority, photographic scale, index scale, focal length of the aerial camera, flight height, date of photography, north arrow,	Although the photoindex primarily facilitates correlation and use of individual photographs, it can serve many other purposes because it is a rough photomosaic of a large area. The scale of the photoindex is usually one–third that of the photographs-- for example, 1:18,000 if the photographs are 1:6,000. The 1–to–3 scale ratio can be changed if the index is needed at a particular scale.

Sample Specifications	Comments
bar scale, and the names of principal planimetric features. The contractor shall deliver one negative of each photo-index sheet and three sets of prints on double-weight semi-matte photographic paper.	
14. Contact prints of the aerial photographs	
The contractor shall deliver _____ contact prints of each frame, trimmed to image edges, on double-weight semi-matte paper.	
15. Disposition of aerial negatives	
Aerial negatives shall be forwarded to the contracting officer after he has accepted all delivery materials specified in Specifications A.13 and A.14.	It may be desirable to permit the contractor to retain the aerial negatives for a specified length of time to allow for rapid preparation of any additional photographic products.
B. GROUND CONTROL SURVEYS	
1. Purpose	
The contractor shall establish sufficient ground control points for controlling individual models or for aerotriangulation.	There are many advantages in having a recoverable network of control available for future needs.
2. Use of existing data	
Horizontal and vertical control has been established, but the condition and recoverability of the marks are uncertain. The contractor shall recover enough stations, or establish new ones, to produce maps that meet the specified map accuracy standards. When practical control points to be used for aerotriangulation should be pretargeted in the field. Established horizontal control monuments are first- or second-order stations adjusted to the North American Datum of 1927	Usually enough data on the location of established horizontal and vertical control are available in the office of the city engineer or other comparable office. In some areas with a great amount of planimetric detail, it may not be necessary to pre-target control points to be used for aerotriangulation. The North American Datum is presently being readjusted with completion scheduled for 1986. It will be referred to as the North American Datum of 1983.

Sample Specifications | **Comments**

(or 1983 if appropriate). Vertical monuments shown are third-order bench marks or better, adjusted to the National Geodetic Vertical Datum of 1929. The contracting authority will furnish survey markers which are appropriate for new stations established by the contractor.

3. Horizontal control

Horizontal control established by the contractor shall conform to second-order Class II standards as stated in the publication "Standards and Specifications for Geodetic Control Networks," National Oceanic and Atmospheric Administration, Federal Geodetic Control Committee, September 1984.

The number and location of new horizontal and vertical control points should be carefully considered. It is important to select locations that can be readily included in the contractor's control survey lines.

At least _____ ground control points shall be established and marked around the perimeter of the project area. All other horizontal control points used for making the maps shall be indicated by a recoverable ground marker. All marked points established by the contractor shall be given "to-reach" descriptions referenced to landmarks and identified by field-survey ties to two or more discrete photoimage points in the immediate vicinity. The location of each marked control point shall be symbolized on the face of the appropriate photograph by a triangle and annotated on the back.

Sample Specifications	Comments
4. Basic vertical control	
Vertical control established by the contractor shall conform to second-order, Class II standards as stated in the publication "Standards and Specifications for Geodetic Control Networks," National Oceanic and Atmospheric Administration, Federal Geodetic Control Committee, September 1984. Permanent monuments shall be established at 1-mile intervals along leveling routes, given "to-reach" descriptions referenced by distance measurements to well-defined image points, and sketched on the backs of relevant photographs.	Types of permanent monuments considered in the spacing requirements can be a rock outcrop or suitable structure, a 4-foot (or longer) aluminum or copper-rod type bench mark with base plate, or a pipe mark with base plate. A permanent magnet in the identifying cap will assist in locating non-ferrous monuments in the future.
5. Reference ties	
Field ties from reference monuments to distinct images (including targets) may be established by a single course from a horizontal control point. Two sets of direct/reverse measurements are required; distances shall be double-taped and limited to 200 feet or measured with an EDM instrument and checked. Control field notes shall comply with these requirements and include a sketch for each identification showing the occupied station, directions or azimuths to adjoining stations, directions and identifications of the images (targets), and a reference to north.	
6. Supplemental vertical control	
Supplemental vertical control may be extended by fly levels to control images if circuit distance or ties between higher order control do not exceed 1 mile. Errors of closure shall not exceed one-tenth contour interval.	

Sample Specifications	Comments
7. Control adjustment The contractor shall adjust all horizontal control to the North American Datum of 1927 (or 1983 if appropriate) and all vertical control to the National Geodetic Vertical Datum of 1929.	
8. Records All field survey records, control descriptions, computations, and related materials shall be delivered by the contractor as specified in the contract.	
9. Technical reference Field survey procedures are defined in the publications "Standards and Specifications for Geodetic Control Networks," National Oceanic and Atmospheric Administration, Federal Geodetic Control Committee, September 1984.	
10. Control identification Control may be identified either before or after compilation photographs are taken, with either natural images or artificial targets.	The locations of section corners, property corners, etc., may be identified by targeting prior to taking compilation photographs. Control-station identification is defined as the identification on a photograph, usually an aerial photograph, of the image of a ground point of known horizontal position and (or) elevation.

Sample Specifications	Comments
11. Accuracy test	
The technical officer for the contract may, at his option, check the accuracy and adequacy of the field survey work before the map compilation work is begun.	An accuracy test of the basic field survey work is usually not necessary, but it is advisable to retain the right to make such a test if there is reason to question the accuracy of the work.

C. PROJECT DESIGN

1. Project area

The boundaries of the project area will be specifically defined, and the number and type of map sheets required to cover the area will be stated.

2. Scale

The map scale will be specified. Typical scales are:

1:240	1 inch = 20 feet
1:480	1 inch = 40 feet
1:600	1 inch = 50 feet
1:960	1 inch = 80 feet
1:1,200	1 inch = 100 feet
1:2,400	1 inch = 200 feet
1:4,800	1 inch = 400 feet
1:9,600	1 inch = 800 feet
1:12,000	1 inch = 1,000 feet

Comments: Typical metric scales would be:

1:250
1:500
1:1,000
1:2,000
1:2,500
1:5,000
1:10,000

3. Contour interval

The contour interval will be specified. For economy, the largest interval that meets user requirements should be selected.

4. Sheet size and orientation

Maximum sheet size shall be 30 by 36 inches. Maximum format should not exceed 25 by 30 inches to provide a minimum margin of 2 1/2 inches. The basis for the map projection will be the proper state plane coordinate system, with the Universal Transverse Mercator projection as an alternative.

Comments: The sheet and format sizes indicated are practical and workable, but they can be altered to fit the specific requirements of a community.

Sample Specifications	Comments
5. Map content	
a. Coordinate grid	
A grid shall be shown at multiples of 5 inches at map scale.	
b. Marginal data	
The following data shall be included in the margin of each map.	These items constitute the minimum information to be shown in the margins. Additional information can be added as desired and as space permits.

Items common to all maps:

- Title block
- Project name
- Project location
- Contracting authority
- Contract number
- Sheet name
- Map scale
- Map type
- Credit notes
- North arrow
- Bar scale
- Accuracy note
- Map location diagram

Items that must be specifically tailored to each map:

- Position in map location diagram
- Adjoining sheet designations
- Geographic coordinates
- Preparation date and photo date
- Road classification
- Route symbols and other special symbols (poles, manholes, culverts, underground utilities).
- Datum
- Required signatures
  - Contracting offical
  - Professional engineer/surveyor
- Revision block

Sample Specifications

c. Planimetry

The maps shall show planimetric features identifiable on or interpretable from the aerial photographs, including such features as buildings; canals, ditches, and reservoirs; trails, roads, highways, sidewalks, and alleys; railroads; ferry slips; fords; quarries and borrow pits; cemeteries; orchards and wooded areas; large lone trees; visible traces of utility lines and their poles and towers; undergound cables; pipelines and sewers; billboards; and fences and walls. Such structures as bridges, trestles, tunnels, piers, retaining walls, dams, power plants, transformers, transportation terminals, airfields, and tanks shall also be shown. Such drainage features as rivers, streams, lakes, ponds, and swamps shall be shown as well as such recreational facilities as parks, golf courses, and athletic fields.

In addition, such features as curbs, sidewalks, parking strips, driveways, hydrants, manholes, and lampposts shall be shown on maps at scales of 1:600 or larger.

Buildings and similar dimensionable objects shall be accurately outlined on the maps to actual scale, except that building dimensions smaller than 1/20 inch at map scale shall be symbolized at 1/20 inch; and minor irregularities in building outlines not representable by 1/40 inch at map scale shall be ignored.

Political boundaries and township, range, and section lines (if any) shall be mapped using the best available sources.

Comments

The planimetric features stated are those generally depicted on large-scale urban maps. If a community does not need to have some of these features shown, they can be omitted from the specifications; conversely, additional features can be added to the specifications. In adding features, however, planners should take care not to increase costs unduly. Features that can be identified and plotted in stereocompilation are no problem, but those that must be identified and positioned by field inspection and/or survey significantly increase the cost of mapping.

Sample Specifications	Comments
Monumented horizontal control stations and bench marks used in making the maps shall be shown. In addition, other permanent control marks recovered during the course of the project shall also be shown, the objective being to present an even distribution of control on the published maps.	
All mapped information shall be shown in accordance with the symbols, style, and lineweights shown in the Appendix, exhibit 4.	
d. <u>Contours and spot elevations</u>	
Contours shall be shown at a vertical interval of ____ feet, and every fifth contour line (or the fourth contour line in the case of, for example, a 2.5-meter contour interval which makes the 10-meter contour line the logical index contour) shall be an index contour and shall be shown with a lineweight heavier than that of the intermediate contours. (See symbol chart for contour lineweights.) Contours shall be shown as solid lines except in areas where the ground is completely obscured by heavy brush or tree cover; in such areas, the contours shall be shown as dashed lines and shall be plotted as accurately as possible from the stereoscopic model, with particular reference to spot elevations measured photogrammetrically in places where the ground is visible.	Dashed contours may not meet standard accuracy. Therefore, the dashed-contour provision may be omitted from the specifications if standard accuracy must be met, regardless of ground conditions, as is often the case when detailed designs for construction work are to be based on maps. But before omitting, consideration should be given to the high cost difference between actual field contouring and photogrammetric contouring.
Spot elevations determined photogrammetrically shall be shown on the maps in proper position at water level on lakes, reservoirs, and ponds; on hilltops; in saddles; at bottoms of depressions; at intersections of principal streets and highways; and at ends of bridges. In areas where the contours are more than 2 inches apart, additional spot elevations shall be plotted to provide additional topographic information; and the horizontal distance between elevations or	

Sample Specifications	Comments
between elevations and contours shall not exceed 1 inch. In areas of uniform slope, at scales 1:1,200 or larger, spot elevations need only be 4 inches apart to locate significant breaks in grade.	

e. Names and labels

The maps shall show significant names data. The following are examples of categories of named features in an urban area:

Corporate, locality, and boundary names

Parks, public squares, monuments, and cemeteries

Linear and hydrographic features

Universities, colleges, public schools, and large private schools

Historic, landmark, and unusually important churches

Shopping centers

Main and secondary streets, railroads, transit lines

The selected names data shall be included in the interior of the map in styles and sizes as shown on the style sheet.

The city name is not shown in the map interior except where more than one city appears on the sheet. Suburb, subdivision, and area names are centered within the area if no boundary or limiting line is shown and legibility is not impaired.

The scale of the map usually determines the density of names data. In maps at a scale of 1:200 or larger, all roads, streets, and alleys are named; all public and major private buildings are named, all churches housed in single-purpose structures are named. In the largest scale maps (1:600, 1:240), dimensional information may be added to water, sewer and storm drainage lines; inverts added to drainage structures; control points named with coordinates and (or) elevations annotated; street addresses added, etc., depending on the intended uses of the map.

Sample Specifications	Comments
Streets and roads are named and spelled in accordance with local usage. Numbered streets are either spelled out or shown numerically in accordance with official designation. For easy identification, names are repeated on long streets or on streets that make abrupt changes in direction. The generic part of the name (street, avenue, etc.) is spelled out in full, if space permits. Names are positioned within the casings of the streets where space permits.	
Important and prominent buildings are named or identified. Normally, individual buildings within a complex are not named or identified.	
6. <u>Finished scribing or drafting</u>	
a. Final maps shall be scribed or drafted on stable polyester with a minimum thickness of 0.004 inch.	If the same map is intended to be used for other purposes at a different scale--for example, a 1:2,400 street engineering map (planimetric version) reduced to a 1:9,600 regional planning map--consideration should be given to increasing the lineweights and symbol sizes to permit production of a dual-purpose map without sacrificing accuracy or legibility at either scale.
b. Symbols, style, and lineweights shall be as shown on the symbol chart. Professional standards of workmanship shall be maintained throughout the scribing or inking of all maps. Each line shall conform to the specified width and remain uniform throughout. The inked or scribed symbols, lines, letters, and numbers shall be clear and legible. If ink is used, it shall be a waterproof, durable ink that will not chip or flake with normal use.	

Sample Specifications	Comments
c. Map reproductions are usually specified as one of the following forms: Reproducible copies of stable polyester with a minimum thickness of 0.004 inch Paper reproductions (either blue- or black-line positives).	As insurance against loss or damage, at least one extra set of polyester reproducibles should be obtained from the contractor and stored at a location different from the place where the original or master set is stored and used. It may be advantageous for the contractor to make and retain an extra set of reproducibles and furnish paper prints, as needed, at prices fixed by agreement. If the contractor is not conveniently located, a similar arrangement could be made with a local reproduction firm. Because paper prints are the usual work medium, it is important that a supplier be readily available.
7. <u>Manuscripts</u> Map manuscripts shall be drawn on stable polyester with a minimum thickness of 0.004 inch at a scale equal to or larger than the final map scale. If the compilation scale is larger than the publication scale, the manuscript shall be reduced photographically and printed on 0.004-inch polyester material for subsequent contact printing of the final bases.	
8. <u>Map accuracy</u>	
a. Coordinate grid lines and horizontal control points shall be plotted within 1/100 inch of true position. b. At least 90 percent of all well-defined planimetric features shall be plotted within 1/40 inch of true position, and the remaining features shall be plotted within 1/20 inch of true position.	The accuracy requirements are from the <u>Reference Guide Outline - Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways</u> prepared by the American Society of Photogrammetry and published by the U.S. Department of Transportation in 1968 except that the RGO specifications call for grid lines and horizontal control points to be plotted within 1/100-inch of true position rather than 1/200-inch. Another widely referenced set of accuracy standards, usually used for smaller scale mapping, is the United States National Map Accuracy Standards,

Sample Specifications	Comments
	U.S. Bureau of the Budget, issued June 10, 1941, revised April 26, 1943 and June 17, 1947. These standards specify horizontally, not more than 10 percent of all points tested shall be in error by more than 1/30-inch on maps published at scales larger than 1:20,000 or 1/50-inch on maps published at scales of 1:20,000 and smaller. Vertically, the standards specify that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval.
c. At least 90 percent of all elevations determined from solid-line contours shall be accurate within one-half the contour interval, and the remaining 10 percent shall be accurate within one contour interval. Any contour that could be brought within this accuracy tolerance by shifting its location 1/40 inch (the allowable horizontal error) will be considered to be acceptable.	
d. At least 90 percent of spot elevations shown on the maps shall be accurate within one-fourth the contour interval, and the remaining 10 percent shall be accurate within one-half the contour interval.	
9. Aerotriangulation	
Analytical aerotriangulation or semi-analytical aerotriangulation may be used to establish supplemental horizontal and vertical control for stereoscopic models, provided that the procedures and equipment (both the aerial camera, the comparator, and the stereoplotter) are approved in advance by the technical officer for the contract.	

Sample Specifications

Comments

10. Map testing and inspection

The technical officer for the contract may inspect the work either in the field or in the contractor's plant at any time. He will check finished maps for completeness by comparison with aerial photographs, field inspection, or both, and will check horizontal and vertical accuracy by running field traverses and profiles. Inspection shall be completed within 60 days after receipt of the maps by the technical officer. The contractor shall be responsible for completing and correcting maps rejected because of incompleteness or inaccuracy.

11. Orthophotographic maps

Specifications concerning area to be covered, scale, contour interval (if applicable), sheet size and orientation, coordinate grid, marginal data, contours and spot elevations (if applicable), map accuracy, aerotriangulation, and map testing and inspection shall be as stated in Specifications C.1, 2, 3, 4, 5a, 5b, 8, 9, and 10.

Applicable only if it has been decided to produce an orthophotographic base rather than a photogrammetrically compiled line base.

12. Orthophotograph preparation

Orthophotographs may be prepared by either simple rectification or differential rectification, depending on the relief difference in a specific aerial photograph. Simple rectification is adequate for photographs containing no more relief than a percentage of the denominator of the final map scale expressed as a representative fraction, as indicated below for different focal length cameras:

Nominal focal length (inches)	Percentage of denominator of map scale
3 1/2	0.2
6	0.3
8 1/4	0.5
12	0.7

For areas with comparatively little relief, simple rectification compensates for displacement in the photographic image caused by tilt of the aerial camera at the instant of exposure. The rectification procedure requires relatively inexpensive equipment and is an economical way to make an orthophotograph. However, for areas of higher relief, displacement is present in the photographic image due to the relief itself, in addition to any displacement due to tilt of the camera. Consequently, a more sophisticated procedure--differential rectification--is needed to produce a true orthophotograph. This procedure requires more expensive equipment and is more

Sample Specifications | Comments

costly than simple rectification, but standard accuracy cannot be attained by any other procedure when the amount of relief exceeds the stated limits.

The percentage assures that displacement in the photographic image due to relief will not exceed the limits specified. For example, differential rectification is required if relief exceeds 7.2 feet for an orthophotographic map at the scale of 1:2,400 made from photographs taken with a 6-inch focal-length camera.

The final orthophotographic map shall not contain scale lines and mismatched imagery that interfere with the interpretability of ground features or that are esthetically objectionable. Mis-matches exceeding 0.04 inch are generally unacceptable and may be cause for rejection. Other defects that could cause rejection include out-of-focus imagery, dust marks, scratches, and inconsistencies in tone and density between individual orthophotos and (or) adjacent map sheets.

13. <u>Contour overlays (if desired)</u>

Contours and spot elevations are to be shown on a transparent overlay, compiled as stated in Specification C.5d. The contracting officer may include, as a delivery item, a set or sets of orthophotographic maps with the contour and spot elevation data overprinted photographically. The contour overlay must be a clear stable polyester with a minimum thickness of 0.004 inch, registered precisely to the orthophotographic map.

If the contours are to be photographically combined into the orthophotographic maps, a choice must be made between black or white lines. This is usually a matter of selecting the version that will have the most contrast considering the predominant tone of the area. Either black or white contour lines can be provided, but the contractor should be informed before beginning work.

Sample Specifications	Comments
14. Reproduction materials Requirement for orthophotographic map reproductions can usually be satisfied in one of the four following forms: (1) stable-base opaque prints on a coated polyester material such as Cronapaque; (2) prints on standard photographic paper, either single or double weight and either semimatte or glossy surface; (3) reproducible, halftone screened (a minimum of 120 lines per inch) positives on polyester base with a minimum thickness of 0.004 inch (for composite photographic and contour reproducibles, only the photographic image should be halftone screened); and (4) paper diazo reproduction made from the screened positives.	Maximum clarity of detail is presented when the orthophotographic maps are printed on photographic paper or on an opaque polyester material, such as Cronapaque. As these prints are expensive compared to diazo paper prints, a set of screened reproducibles should be obtained so that inexpensive work copies can be made in quantity.

APPENDIX 19-2

Sample Contract Specifications
for Parcel Mapping

From Standards on Cadastral Maps and Parcel Identifiers
(IAAO (1988))

Technical Specifications for Property Ownership Mapping

Phase 1—Rectified Vertical Aerial Photography

Vertical aerial photography needed for this project shall be provided by the county. This may consist of aerial photography the counties have had flown in the last three years or any newly acquired aerial photography. All photo enlargements must meet the requirements as described in the specifications for rectified vertical aerial photography.

1.1 The contractor shall review and edit each photo enlargement as it is received for scale accuracy, clarity, correct placement of the image area on the screened mylar, correct placement of section corners, proper labeling, and proper butt-matching. This review and edit shall be accomplished prior to the layout and design phase or any preliminary mapping. Any photo enlargements found to be deficient will be returned by the contractor to the county for proper disposition.

1.2 The photography as provided by the county will be used as the base in the construction and preparation of the property ownership maps and will consist of the following:

1.2.1 A high altitude flight for obtaining 1" = 2000' negative scale aerial photography to be used in producing a complete set of rectified aerial photo positive screened enlargements at the scale of 1" = 400' containing four sections of land two miles square, as shown on the "Contract Map" of the county.

1.2.2 A low altitude flight for obtaining 1" = 500' negative scale aerial photography of the *highly* urbanized areas of cities, towns, and villages requiring the scale of 1" = 100' rectified photo positive screened enlargements for proper tax mapping. Each 1" = 100' photo enlargement shall represent one-quarter of a section of land one-half mile square, resulting in four reproductions to a section where applicable.

1.2.3 One photo index and one complete stereo set of contact prints of the 1" = 2000' negative scale aerial photography covering the entire county. The photo index shall be produced on 4 mil, dimensionally stable, double-matte polyester film.

1.2.4 One photo index and one complete set of contact prints of the 1" = 1000' negative scale aerial photography and 1" = 500' negative scale aerial photography of the towns, cities, villages, and any other urbanized areas as outlined on the "Contract Map" of the county.

Each index shall be produced on 4 mil, dimensionally stable, double-matte polyester film.

1.2.5 The photo index base may be either a mosaic of the contact prints or a reproduction of the county highway map on 4 mil, dimensionally stable, double-matte polyester film.

1.2.6 Any other photography products in the county's possession necessary to complete the mapping program.

Phase 2—County's Recorded Records

The contractor shall use any part of the county's recorded records as may be necessary to construct new property ownership maps as follows:

2.1 The Register of Deeds' grantor and grantee indexes, deed books and/or microfiche or aperture cards for making deed copies

2.2 The Register of Deeds' mortgage books

2.3 The Register of Deeds' field maps, plats, subdivision plans, and surveys

2.4 The Probate Court's will books, and so on

2.5 The Appraiser's records, consisting of any existing lot books, tract books, assessed descriptions, property record cards, index cards, and so on

2.6 The County Clerk's records of annexations, street or alley closings or openings, taxing district boundaries and descriptions, assessment rolls, transfer books, and a current taxing unit map showing the number and metes and bounds of every taxing unit or any portion of a taxing unit located within the county

2.7 Any other state or county office or agency that has recorded information relating to political subdivision boundaries including, but not limited to, district courts, city clerks, city engineer's offices, and planning and zoning commissions

It shall be the company's responsibility to use any part of items 2.1 thru 2.7 when these pertinent record copies are required to properly prepare the new property ownership maps under the technical specifications as set forth herein.

The county agrees to make every reasonable effort to provide access to the above items during normal office hours and at other times as determined by the parties.

Phase 3—Source Document Collection

The company shall make a reasonable attempt to locate, copy, and deliver to the county the following additional mapping aids:

3.1 Original township plats and surveyor's field notes used in the establishment of township, range, and section lines.

3.2 Rights-of-way acquisition surveys or plans for all federal, state, city, and county roads, streets, or highways that currently exist in the county.

3.3 1:24,000 United States Geological Survey (USGS) 7 1/2′ SERIES Topographic map sheets covering the entire county.

Note: The State of ____________ has complete 7 1/2′ SERIES coverage.

3.4 Railroads, cross-country utility rights-of-way plans, and all trunkline pipeline easements.

3.5 In counties having a county surveyor/engineer, the county agrees to have him or her available for consultation with the contractor during normal courthouse office hours and at such other times as is practical.

Phase 4—Work Index Card Preparation

4.1 The director and his staff shall prepare and design a work index card to be used by the county and the contractor for each parcel of land to be mapped. The size of the work index card shall be 8½-by-11 inches. The most current and complete assessment records, land rolls, or property record cards shall be used as the initial source of information to prepare the work card. The information to appear on the work card will include, but not be limited to, the following:

4.1.1 Taxing district names or numbers or taxing unit numbers, where applicable

4.1.2 The owner's name or names and taxpayer's name if different from owner of record

4.1.3 The owner's mailing address or addresses and taxpayer's address if different from owner

4.1.4 The existing map, plat, or account number, if any

4.1.5 The parcel's location by address, road, street, or house number (if available)

4.1.6 The original section number, township, and range

4.1.7 The original realty or subdivision name, lot, and block number

4.1.8 The lot size or parcel acreage where applicable

4.1.9 The parcel description as contained on the assessment records, land rolls, or property record cards

4.1.10 The deed books and page numbers or recordation reference to vesting instruments, if available (if the deed book and page numbers are not available from assessment records, book and page numbers will be added to the work index card during the parcel delineation phase as described in 6.2)

4.1.11 Any other information as may be contained on the assessment records or land rolls that would facilitate the property ownership mapping program

4.2 The work index card shall be designed so that additional information can be added as the parcel encounters the various phases of the mapping program. Examples of additional information that would be applicable are:

4.2.1 An area designated for the permanent UNIFORM parcel number

4.2.2 An area for calculated acreage (if applicable)

4.2.3 An area for scaled dimensions (if applicable)

4.2.4 An area for updated owner name or names

4.2.5 An area for change of mailing address

4.2.6 An area for the updated property description, where necessary

Note: See Phase 6.3 for correct procedures on writing property descriptions.

4.2.7 The card shall be designed so that notes used for an explanation of ownership or boundaries, if different from the description in the conveying instrument, assessment records, or field call information, can be recorded.

4.2.8 The work index cards shall be arranged in geographical or map number order.

Phase 5—Layout And Design

5.1 Prior to the determination or delineation of individual property ownership lines or boundaries, the contractor shall complete a layout and design phase.

The layout and design phase will be the beginning of the construction of a work, or preliminary, property ownership map. The work, or preliminary, property ownership map shall be drawn on 2 mil, dimensionally stable, single-matte transparent film material or the equivalent. There shall be a work map created for each final property ownership map in the county. The work map shall consist of an overlay, as stated above, of each enlargement or a duplicate enlargement.

No preliminary work shall be done on the photograph *itself*, other than the inking of registration marks on the four corners of the image area. These registration marks will also be placed on the preliminary work map as well as on the final drafted map sheet. This is to ensure that when the photo enlargement and the final map sheets are placed together, the detailed line work will match exactly as it has been mapped for producing a composite print. During the layout and design phase, the following detail shall be plotted:

5.1.1 Using the rights-of-way, acquisition surveys, or plans, all public road, street, and highway rights-of-way will be made to register with the physical and cultural features on their corresponding screened enlargements *as often as possible*. Indications of the location of the section, townships, and range lines, or corners shown on the rights-of-way plans will be considered in verifying the corners as shown on the aerial photographs or plotting same when not shown on photograph.

5.1.2 Using the original township plats, surveyor's field notes, and USGS topographic maps as an aid, the contractor shall verify or confirm the location of section, township, and range lines and corners. The section, township, and range lines, and proportionate division lines of sections shall be made to register with the physical and cultural features on the corresponding screened enlargements *as often as possible*. As the section, township, and range lines are the mapping limit lines for each property ownership map, the contractor shall pay particular attention to the location of section, township, and range lines from map to map. This will result in the filling of any gaps or omission of overlaps between maps and will assure a proper and adequate butt-match of all maps. It is specifically understood that all maps must be butt-matched on all sides prior to delivery to the county.

5.1.3 Using plans or surveys, all railroad and cross-country utility rights-of-way shall be drawn to the proper property ownership mapping scale. The rights-of-way will be made to register with the physical and cultural features on their corresponding screened enlargement *as often as possible*.

5.1.4 All recorded surveys and subdivision plats shall be plotted to the proper property ownership mapping scale. All acreages, overall parcel dimensions, street names, original lot and block numbers, and subdivision names shall be shown. The recorded surveys and subdivision plats shall be made to register with the physical and cultural planimetric features on their corresponding screened enlargement *as often as possible*.

5.1.5 A "County Index Map" shall also be developed during the layout and design phase, delineating and assigning a permanent map number to the various 1" = 400', 1" = 200', and 1" = 100' property ownership mapping areas of the county. The index map shall be developed utilizing the county highway map negative and depicting all road networks and other major planimetric detail. A separate index of the areas enlarged to 1" = 200' and 1" = 100' shall be developed in the same manner as the master "County Index Map." Each enlarged area shall be labeled according to the name of the city, town, village, or corporation it represents. Permanent map numbers shall be depicted on all index maps within the map area itself.

Note: An example of a "County Index Map" shall be made available by the director.

5.1.6 Once the layout and design have been completed, a listing of all recorded subdivisions in the county shall be developed. Each subdivision shall be listed in alphabetical order indicating the following:

1. Map or map numbers where subdivision is shown

2. Plat books and page numbers where subdivision is legally recorded

Phase 6—Work, or Preliminary, Ownership Map Compilation

The company shall prepare the work maps according to the following:

6.1 Definition of a parcel

The State of ________ has adopted the following definition of a "parcel" for the purposes of these mapping specifications: "a contiguous area of land within a section under one ownership, that can be included under one description for assessment or appraisal purposes, after consideration of all *legal* and *practical* elements." The following conditions or factors shall affect the actual parcel boundaries:

6.1.1 Tax district or taxing unit boundaries shall *split* contiguous ownership into *separate* parcels. A dashed tie bar shall be used across the district or unit boundary line to indicate same ownership, but separate parcels. Exceptions to this rule are subdivided lots that are already described in their smallest legal division. When a taxing district or unit line cuts through a subdivision lot, it shall be parcelled in the district where the largest volume of land occurs or where the improvement is located, wherever practical.

6.1.2 All large rural tracts of land described under the Rectangular Survey System that are split by a right-of-way (road, railroad, utility) and physical features (creek, streams) shall still be considered one parcel. This would apply on 1" = 400' maps and, in some cases, on 1" = 200' where larger rural properties are depicted on maps with smaller subdivided parcels requiring 1" = 200' for proper tax mapping.

6.1.3 On 1" = 100' maps, rights-of-way shall split contiguous ownership into separate parcels.

6.1.4 If a parcel crosses a section line, a new parcel shall be created and tied to the other parcel with the use of a dashed tie-bar. The exception to this shall be where a small part of a tract (two acres or less, not subject to further division) extends into an adjoining section. In this case, the section line shall be shown in a dashed form where it goes through the parcel.

6.1.5 Subdivided lots shall not normally be split by a section line. Refer to item 6.1.1.

6.1.6 Several subdivision lots covered by a single improvement and under one ownership, shall be considered one parcel.

6.1.7 An entire subdivision block of lots, used as a unit and under one ownership, shall be considered one parcel.

6.1.8 An area covered by an industrial plant, hospital, or city or county entity, even though the tract encompasses different subdivisions as well as sectionalized land, would be considered one parcel.

6.1.9 Any vacant undeveloped subdivision with all lots in one block in the name of one owner shall be one parcel.

Note: Where the county has identified to the contractor several blocks of a subdivision under one ownership, the contractor shall combine all the blocks into one parcel *where practical* for appraisal purposes.

6.1.10 Quarter-section lines or other divisions of the section do not constitute a separate parcel, even though the properties were acquired at different times under separate deeds. All tracts contiguous and under one ownership within a section shall be considered one parcel, where practical.

6.1.11 On 1" = 100' maps where the map boundary is the quarter-section line or a simple match line and the parcel cannot be depicted in its entirety on a single map sheet, the parcel shall be controlled on one sheet (usually where the largest volume of land exists or where the improvements are located). The area of the parcel on the adjoining map shall be included with the area on the map where the parcel is controlled and, "see notes" shall be shown on both maps indicating the controlling map number and the map number for balance of area of the parcel.

6.1.12 Improvements on leased land that require a separate appraisal and assessment and for which proper documentation is provided by county will be assigned a separate parcel number as described in Phase 9 of these specifications.

6.1.13 For mineral interests or mineral rights that are severed from ownership of the surface rights and require a separate appraisal and assessment and where proper documentation for those severed rights or interests are provided, a separate parcel number shall be assigned as described in Phase 9 of these specifications.

6.1.14 Condominiums shall be treated the same as any other tract of real property. Each condominium unit shall be assigned a separate parcel number, where applicable, as described in Phase 9 of these specifications.

6.1.15 Although other variations of parcel configurations exist, such as (1) contracts for deeds, (2) parts of properties or tracts that are mortgaged to a lending institution, (3) portions of a tract of land that are put into trusts, and (4) life estates that are reserved to the grantor or where life estates are granted, it is the intent of the director of the Division of Property Valuation that parcel configurations be limited to the definition as contained in 6.1 and as modified in 6.1.1–6.1.14.

Note: It is expressly understood that *conditions* or *factors* affecting parcel boundaries not listed in 6.1.1–6.1.14 shall be considered without the express, prior, and written approval of the director of the Division of Property Valuation.

6.2 Parcel Locations, Plotting, and Delineation

The location and the plotting of the parcels shall be accomplished through the use of the existing source maps and the description as contained in the vesting instrument or assessment records in conjunction with the delineation of the parcel's boundaries and limits, as distinguishable from the physical and cultural features of the *photo enlargements.*

All parcels shall be plotted from the vesting instrument description. A copy of this instrument shall be attached to the map work card. The exception to this shall be parcels with whole lot and block descriptions in subdivisions where deed books and page references exist. Those parcels with parts of lots descriptions shall have a deed attached to the work card. In the event a parcel ownership boundary cannot be delineated or determined through the use of existing source maps, assessment record descriptions, recorded surveys of plats, or vesting instrument description, the following priorities of calls shall be used:

6.2.1 Natural boundaries

6.2.2 Man-made boundaries

6.2.3 Contiguous owners

6.2.4 Distance

6.2.5 Course (bearing or direction)

6.2.6 Area

6.3 Property Descriptions

6.3.1 If in the process of locating and plotting the parcels, it becomes evident to the compiler that the property description as contained on the assessment records (tax roll, land roll, or property record card) does not adequately locate and describe the parcel, the compiler shall write a new property description in the space provided on the map work card.

6.3.2 That portion of the legal description contained in the vesting instrument used in the plotting of the parcel shall be highlighted, bracketed, or underlined during this process for future verification and editing.

6.3.3 Parcel descriptions containing wording such as, pts. of sec., 1/4 sec., or 1/4 1/4 sec. or any other terms that do not adequately locate and describe the property as mapped, shall not be acceptable.

6.3.4 All property descriptions using the U.S. Rectangular Survey system of describing parcels shall be written as follows where applicable: (NE 1/4), (NE 1/4 NE 1/4), (E 1/2 NE 1/4 NE 1/4), (S 33O' of NE 1/4 NE 1/2), (E 325' of S 33' of NE 1/4 NE 1/4), (W 425' of NE 1/4), (S 2O8' of W 425' of NE 1/4), (SE 1/4 lying N of Rye Creek), (E 1/2 of SE 1/4 lying S of Rye Creek). These are only a few examples of descriptions that can be written as part of the U.S. Rectangular Survey.

6.3.5 When writing descriptions using metes and bounds methods of describing parcels, the description *must* contain a beginning point, directions and dimensions around the parcel (usually clockwise), and a closing to the point of beginning. Example: Beg. at a pt. on N side of U.S. Hwy 24 385' W of E Line of sec. th. N 272', E 35O', S 272', W 35O' to P.O.B.

6.3.6 All property descriptions, whether U.S. Rectangular Survey or Metes and Bounds, must be written using features that are *identifiable* on the property ownership maps.

6.3.7 Where tracts of land listed on the assessment records must be combined into one parcel, according to the parcel definition in 6.1 of these specifications, then a new property description shall be written and placed on the map work card in the appropriate space.

6.3.8 Where tracts of land listed on the assessment records must be split into two or more parcels, because of conditions listed in 6.1 of these specifications, then a new property description shall be written and placed on the map work card in the appropriate space.

Property descriptions shall be written in brief, specific terms, but will be adequate to locate and describe each parcel exactly as it is depicted on the map sheets.

Sample disclaimer for the work index card:

It is specifically understood that the *property description* is used to locate, identify, and inventory each parcel of land within a taxing jurisdiction for appraisal and taxing purposes only and is not to be construed as a ***legal description.***

6.4 All ownership mapping shall be limited to the absolute "fee simple" state. All public utility "high line," pipeline easements and other cross-country easements determined to affect value shall be mapped showing the dimensions and limits of the easements.

6.5 Field Interviews

In the event property ownership or parcel boundaries cannot be determined from the procedures as described in 6.2 of these technical specifications, a field interview shall be required.

The contractor shall make an effort to contact the owner or someone knowledgeable about the ownership and boundaries of the parcel or parcels in question. Field interview notes shall be added to the work index card for the parcel or parcels in question. The notes shall describe and explain the efforts made by the company in order to resolve the problem or discrepancy. This information shall be delivered to the county periodically so that they may try to resolve the problems. In the event the county cannot resolve the discrepancy, the contractor's notes shall be kept for future reference.

6.6 All information to appear on the property ownership maps shall be in a standard format and shall include, but not be limited to, the following:

6.6.1 The property lines (limits of ownership) shall be delineated by solid lines. Where a water line is the property boundary, the symbol for water line shall be shown in at least one place along the water boundary.

6.6.2 The original U.S. Survey lot divisions and subdivision lot lines shall be shown by tick marks, together with block numbers, the original lot numbers, and the government survey, section, township and range, and U.S. Survey lot identification, when appropriate.

6.6.3 The dimensions of all platted parcels shall be indicated to 1/10th of a foot, where known, regardless of area. These figures shall not be rounded either up or down from the 1/100th of a foot when used. Scaled dimensions shall be shown to the nearest foot with a (s) symbol shown beside the figure.

6.6.4 Parcels of one acre and over shall show the acreages either from the assessment records, the recorded map references, the deed of record when used, or as calculated (c), when deed or assessed acreage is not known. Example: 27ac(c).

Note: Where the parcel boundary as described in the deed is still intact, the deed acreage will take precedence over assessed acreage.

Parcels of under one acre shall show dimensions either from the assessment records, the recorded map references, the deed of record when used, or, absent deeded or platted dimensions, as scaled (s). Example: 125(s) x 175(s). Parcels over one acre and less than five acres will show dimensions and acreages.

6.6.5 The state, county, city, town, village, township, and section lines shall be shown and labeled at their approximate locations on the map from the best information available.

6.6.6 Taxing unit boundaries shall be shown and labeled at their approximate location only when they divide properties into separate parcels.

6.6.7 The cemeteries, churches, hospitals, public buildings, public lands, and parks (federal, state, county, city, township, town, and village) shall be shown and indicated by their names, when known.

6.6.8 The state, county, city, town, and village lines shall be shown and labeled on the ownership maps by their appropriate names. The labels shall appear on the inside of the line that they encompass.

6.6.9 The railroads, roads, streets, and rights-of-way shall be shown and labeled by their correct names or numbers, when known. The U.S., state, and county highways shall be shown and labeled by their correct symbols, route numbers, or names, when known. All railroads, roads, streets, and utility rights-of-way shall show dimensions in all cases.

6.6.10 The drainage features shall be shown and labeled by their correct names, when known. Drainage features shall be such items as lakes, rivers, reservoirs, ponds, dams, streams, brooks, and swamps.

6.6.11 Each ownership map sheet shall have a title block containing the map number, the map scale, the mapping date, a north arrow, the adjoining map block, a mapping legend, and a revision block to indicate future maintenance.

6.6.12 The permanent parcel identification numbering system shall be shown with the correct number assigned to each parcel.

Phase 7–Area Calculations

When acreages or lot dimensions, as listed in the current assessment information by the county, do not agree with the acreages or lot dimensions as determined by the preparation of the new ownership maps, these acreages and lot dimensions shall be determined by the contractor as follows:

7.1 The area (acreage) of all parcels greater than one acre shall be calculated and checked against their assessed acreage or the recorded deed acreages. All acreages shall be verified using an electronic digitizer or polar planimeter. If a polar planimeter is used, each computation shall be based on the average of three separate readings. When the calculated acreage varies from the assessed or the recorded deed acreage, the following sliding scale shall be used in determining the acreage to be placed on the new ownership maps, with each calculated area followed by the suffix (c):

Over 1 acre up to 10 acres	5% difference
Over 10 acres up to 40 acres	4% difference
Over 40 acres up to 160 acres	3% difference
Over 160 acres up to 640 acres	2% difference

When calculated acreages do not agree and vary from the assessed or recorded deed acreages by the percentages listed above, then both the calculated and the assessed or deeded acreage shall be placed on the new ownership maps. Example: 40 ac(d), 43 ac(c). All calculated acreages shall be rounded down to the nearest tenth from one acre up to and including ten acres, the nearest half from eleven up to and including fifty acres, and the nearest acre above fifty acres.

Phase 8–Dimensions

8.1 The *dimensions* of parcels under five acres shall be obtained from the assessment records, the recorded map reference, or the deed of record when used in preparation of the new ownership maps. Only the width and depth dimensions shall be indicated on the rectangular shaped lots. Parcels that are irregular in shape shall have dimensions shown on each boundary line. When displaying the dimensions on the work index card, only the front dimension of the parcel and the longest side are necessary. Example: 150' x 195' IRR. When the lot dimensions cannot be obtained to fulfill the above requirement, then the dimensions shall be scaled and placed on the new ownership maps with each scaled dimension followed by a suffix letter (s). Using Cadastral Map Accuracy Standards of + 1/20" the following would apply on 1" = 100', + 5'; 1" = 200', + 10'; and 1" = 400', + 20'.

Phase 9–Permanent Map and Parcel Numbering System

The permanent ownership map and parcel numbering system, as herein described, shall be used to identify all the properties within the county. It is designed to provide instant location of each parcel geographically within the county, as well as within each ownership map sheet. The numbering system shall be incorporated into the county's assessment records and shall be used to facilitate computerization of all parcels inventoried within the county.

9.1 Permanent Map Numbers

The county shall be divided according to the legal division as determined by the U.S. Rectangular Survey of Public Lands.

The concept of this system is to provide a uniform format for the instant location of each division of a geographic area. The first number in each series occurring within subsequent divisions of a geographic area shall always occur in the northeast corner of each division. The actual map number shall be as follows:

9.1.1 The 1" = 400' scale ownership map sheets shall consist of one set of numbers containing a maximum of three digits. The first division within the county is the township consisting of thirty-six sections of land six miles square. Each township shall be assigned a new number rather than the current reference to the legal township and range and shall consist of the first two of the three digits in the map locator number. The township shall be numbered sequentially from east to west and west to east in a serpentine manner within the county so that the easternmost township in the most northerly tier would be numbered 01. The third digit in the map locator number will be the four-section area of the township contained by the map. There will be nine map areas in each township and they shall be numbered sequentially in the same manner as the townships. The first number, 1, will be the northeasterly four sections of the township and 9, the southwesterly four sections. Each four-section area number shall remain constant with the section numbers to which it is assigned.

An example of the 1" = 400' scale map number is 011. The first two digits, 01, represent the first township within the county and the last digit, 1, the four-section area of the township itself, in this case sections 1, 2, 11, and 12.

Note: When an area on a 1" = 400' scale map will not fit the standard format, the area must be split and depicted on more than one sheet; it will not be necessary to use more than the three digits described above. A decimal number will simply be added to the section number in the total permanent parcel number.

Example: 011 – 01.1
011 represents the map number.
01.1 represents the legal section and the first sheet of the divided four-section area.

9.1.2 The 1" = 200' scale map sheets shall consist of two sets of numbers containing the township and area location with the addition of a two-digit number identifying the actual legal section, 01 through 36, depicted on the map.

Example: 011 – 01.
011 represents the township and four-section area.
01 represents the legal section.

Note: In those counties with elongated or extra wide sections along the northern and western tier of sections in townships with survey error adjustments, it will be necessary to add a decimal number to accommodate the splitting of sections onto more than one sheet, because each sheet must contain its own group of parcel numbers in order to be unique.

Example: 011 – 01.1
011 represents the township.
01.1 represents the legal section and the sheet number that this part of the section is assigned.

9.1.3 The 1" = 100' scale map sheets shall consist of three sets of numbers containing the township and four-section area number, the legal section number, and a two-digit number identifying the actual quarter section, the northeast (NE 1/4) being 10, the northwest (NW 1/4) being 20, the southwest (SW 1/4) being 30, and the southeast (SE 1/4) being 40.

Example: 011 – 01 – 10
011 represents the township and four-section area.
01 represents the legal section.
10 represents the quarter section, in this case the northeast quarter (NE 1/4).

9.1.4 The 1" = 50' scale map sheets, where necessary, would follow the same sequence as described in 9.1.3 for 1" = 100' scale map sheets. The map number shall consist of the same three sets of numbers: township and four-section area number, the legal section number, and the two-digit number identifying the quarter section and quarter quarter section. This division shall follow the same pattern used for dividing the section into quarters. The NE/NE shall be 11, the NW/NE shall be 12, the SW/NE shall be 13, and the SE/NE shall be 14.

Example 011 – 01 – 14
011 represents the township and four-section area.
01 represents the legal section.
14 represents the quarter section and quarter quarter section, in this case the SE/NE.

Note: Special circumstances may dictate deviation from the numbering pattern described in 9.1.3 and 9.1.4; however, careful review of this system indicates that it will not be necessary to use more sets of numbers or digits than those described.

Map Numbering Summary

1" = 400' map sheets: one number, three digits.
1" = 200' map sheets: two sets of numbers, five digits, or in the case of split sheets seven digits, including the decimal number identifying each sheet.
1" = 100' or 1" = 50' map sheets: three sets of numbers containing seven digits or, in the case of split map sheets, nine digits including the decimal number identifying each sheet.

Possible map number configurations:

1" = 400' scale map (011)
1" = 200' scale map (011 – 01) or (011 – 01 – 1)
1" = 100' scale map (011 – 01 – 10) or (011 – 01 – 1)
1" = 50' scale map (011 – 01 – 11)

9.2 Permanent Parcel Numbers

The actual grouping of the parcels into manageable units and the assignment of final parcel numbers shall be as follows:

9.2.1 On 1" = 400' scale maps, each section shall constitute a group of parcels. The assignment of the first parcel number shall begin in the northeast corner of each section and continue counterclockwise, where possible, through the last parcel within that section. The number shall be displayed on the work index card in the manner indicated below.

Example: (1" = 400') MAP NUMBER 011

UNIFORM PARCEL NUMBER

Map Area No.	Section	1/4 Sec.	Block No.	Parcel No.	Ownership Code
011	01.0	00	00	001.00	0

The map area number, the section number, and the final parcel number shall be entered in the appropriate space. The space for quarter section and map block number shall have zeros (00) entered.

9.2.2 On 1" = 200' scale map sheets, grouping of the parcels into blocks shall be accomplished by using physical and cultural features such as roads, creeks, or some other planimetric feature such as the dimension. Block numbers shall commence in the northeast corner of the map sheet and shall run in a serpentine manner from east to west and west to east, where possible, through the last block on the map sheet. The assignment of the actual parcel number shall begin in the northeast corner of each map block and shall run counterclockwise around each block or area, where possible. The map and parcel number shall be displayed on the work index card as indicated below.

Example: (1" = 200') MAP NUMBER 011 – 01

UNIFORM PARCEL NUMBER

Map Area No.	Section	1/4 Sec.	Block No.	Parcel No.	Ownership Code
011	01.0	00	01	001.00	0

The map area number, the section number, the block number, and the parcel number shall be entered in the appropriate space. The space for the quarter section shall have zeros (00) entered.

9.2.3 On 1" = 100' scale map sheets, grouping of the parcels into manageable units shall be accomplished in the same manner as described in 9.2.2 for 1" = 200' maps. Each block shall have a separate map block number assigned, commence in the northeast corner of the map sheet, and run in a serpentine from east to west and west to east to the bottom of the map sheet. The assignment of the actual parcel number shall commence in the northeast corner and shall run in a counterclockwise direction around each map block or area. The map and parcel number shall be displayed on the work index card as indicated below.

Example: (1" = 100') MAP NUMBER 011 – 01 – 10

UNIFORM PARCEL NUMBER

Map Area No.	Section	1/4 Sec.	Block No.	Parcel No.	Ownership Code
011	01.0	10	01	001.00	0

The map area number, the section number, the quarter section number, the map block number, and the final parcel number shall be entered in the appropriate space.

9.2.4 On 1" = 50' scale map sheets, where necessary, the assignment of block and parcel numbers shall follow the same pattern as described in 9.2.2 and 9.2.3 for the 1" = 200' and 1" = 100' maps. The only difference in the numbering configuration will be in the quarter section number. This two-digit number shall consist of the first digit representing the quarter section and the second digit representing the quarter quarter section. The map and parcel number shall be displayed on the work index card as indicated below.

Example: (1" = 50') MAP NUMBER 011 – 01 – 14

UNIFORM PARCEL NUMBER

Map Area No.	Section	1/4 Sec.	Block No.	Parcel No.	Ownership Code
011	01.0	14	01	001.00	0

The map area number, section number, quarter quarter, block number, and parcel number shall be entered in the appropriate space. Splits, leaseholds, condominiums, mineral rights, and so on shall be numbered in accordance with the following guidelines:

9.3.1 *Splits.* Once the final map sheet has been completed and permanent parcel numbers have been established for each parcel, the map shall be considered to be part of the ongoing maintenance. The split-off shall be assigned the original number from which the land was sold with the addition of a decimal number to identify the split portion.

Example: The owner of record of parcel number 12 sells a portion off. That portion that was sold off shall be assigned the number 12.01. That portion still owned by the original owner shall retain parcel number 12 and the assessment records shall be changed to reflect that portion remaining.

9.3.2 *Condominiums.* The tract of land or lot on which a condominium complex or development is located shall be assigned a whole number as the permanent parcel number. Each condominium unit within the complex shall be assigned a decimal number in the same manner as split-offs described in 9.3.1 above.

Example: The tract of land containing the condominium units is assigned parcel number 15. One condominium unit located on this tract shall be assigned the number 15.01, a second, 15.02, and so on through the last unit in the complex.

9.3.3 *Leasehold Improvements.* Buildings or improvements located on land that is under a documented lease, as provided by the county, and requiring separate appraisals and assessments shall have a parcel number assigned to them.

The land being leased for the improvements shall be indicated on the map sheet with the use of a dashed line to encompass the leasehold. That area under lease shall be assigned the number from the original parcel with the addition of a decimal number to identify the leasehold.

Example: The tract of land where the lease occurs has been assigned parcel number 20. That portion being leased shall be assigned parcel number 20.01, where applicable. If the entire parcel is being leased for an improvement, the same concept would apply—a parcel number for the land owner and a parcel number for the leasehold improvement.

9.3.4 *Mineral Rights.* In those instances where mineral rights ownership is severed from the surface rights ownership and proper documentation is provided, a parcel number shall be assigned to the severed rights. All severed mineral rights ownerships, contiguous within a section, shall constitute one mineral rights parcel, regardless of the number of surface rights parcels the severed rights encompasses. When the mineral rights parcels do fall under several parcels within a section, then the parcel number to be assigned shall be the first number in the parcel number series encountered by the mineral rights, or the number of the parcel in the northeast corner, wherever practical. The basic parcel number with the addition of a decimal shall be used to identify the mineral rights.

Example: Contiguous mineral rights ownership falls under parcels 1 through 15. The mineral rights number in this case would be 1.01. The total acreage contained in the mineral rights ownership would be shown on the map sheet and the work index card in the appropriate space.

9.3.5 *Ownership Codes.* The work index card is designed to accommodate an ownership code number to identify the different variations of real property ownership as follows:

0 = Ownership code number for fee simple title (to be used for split-offs of fee simple also)
1 = Ownership code number for identifying leasehold improvements
2 = Ownership code number for identifying condominium unit ownership
3 = Ownership code number for identifying severed mineral rights ownerships

Phase 10—Field Edits, Errata Lists, and Conflicting Ownerships

The contractor shall resolve and/or record the discrepancies found in the preparation of the ownership maps as follows:

10.1 A field edit shall be made to locate, delineate, and determine the ownership of the properties not presently listed in the assessment records and the unresolved problems found in the compilation of the ownership maps.

10.2 The contractor shall verify each listing on the current land roll (tax roll) used during the mapping project. Each listing shall be identified by a map and parcel number.

10.3 A list shall be prepared of any and all properties not accounted for on the land roll (tax roll), and a copy of the list shall be delivered to the county before final approval.

10.4 A list shall be prepared of any and all doubly assessed property found to exist, and said list shall be delivered to the county before final approval.

10.5 A list shall be prepared of all taxable and exempt parcels contained on the land roll (tax roll) that cannot be located or reconciled on the ownership maps.

Note: The contractor shall make every effort possible in an attempt to resolve any problems described in 10.1 through 10.5 above and shall record those efforts in the proper space on the map work card in the same manner as described in 6.5 of these specifications.

Phase 11—Title Block and Legend

11.1 The director of the Division of Property Valuation shall design and prepare a title block and legend, which shall be shown on each final property ownership map sheet. A sample of the title block and legend shall be issued to each county. Minimum information to be contained in the title block and legend area of each sheet shall be as follows:

11.1.1 County name
11.1.2 State name
11.1.3 Name and address of mapping contractor
11.1.4 Scale bar and scale of map
11.1.5 North arrow
11.1.6 Outline of county showing original township and range designations

11.1.7 A thirty-six section township, with each map sheet located therein emphasized
11.1.8 Section index showing particular quarter section mapped on each 1" = 100' sheet
11.1.9 Date of map
11.1.10 Date of photography
11.1.11 Aerial photograph number
11.1.12 Symbols and definitions used in construction of maps
11.1.13 Revision block
11.1.14 Original township, range, and section numbers
11.1.15 Map number
11.1.16 Disclaimer (a statement to the effect that the property ownership map is for tax purposes only and is not intended for use in making conveyances or preparing legal descriptions of properties)
11.1.17 A subdivision plat index.

Phase 12 – Final Map Drafting

The company shall mechanically ink draft the final property ownership maps as follows:

12.1 The final property ownership map shall be prepared on 4 mil, dimensionally stable, double-matte polyester film such as Mylar, Cronaflex, or the equivalent.

12.2 The sheet size of the final property ownership map shall be 36" x 36".

12.3 All drafting, including lettering and numbering, shall be done with standard LeRoy, or approved equivalent, mechanical drafting equipment consisting of templates and pens. Free-hand lettering or numbering shall not be acceptable except for water features. Final drafting shall be done using Pelican TN ink or an approved equivalent.

12.4 To assure uniformity of line weight, lettering and symbols, the following drafting standards shall apply. The drafting standards shown here are subject to modification in *special cases only*, and then only in the interest of increased legibility and utility if approved in writing by the director of the Property Valuation Division.

12.5 Glossary of terms and abbreviations for final property ownerships maps:

Acre	Ac	Not Recorded	NR
Addition	Add	North	N
Avenue	Ave	Number	No
Baptist	Bapt	Page	Pg
Boulevard	Blvd	Place	Pl
		Plat Book	PB
Catholic	Cath	Presbyterian	Presby
Cemetery	Cem	Property	Prop
Circle	Ci		
County	Co	Railroad	RR
Court	Ct	Railway	Rwy
Creek	Ck	Range	R
		Revised	Rev
District	Dist	Rights-of-way	R/W
Drive	Dr	Road	Rd
Easement	Ease	Section	Sec
East	E	South	S
Estate	Est	Street	St
Extension	Ext	Subdivision	S/D
Exempt	Ex	Township	Tsp or T
Highway	Hwy	Trail	Tr
Heights	Hgts		
		Village	Vill
Lane	La		
		West	W
Methodist	Meth		

12.6 PEN WEIGHT AND TEMPLATE GAUGE FOR 1" = 200', 1" = 100' MAPS

SUBJECT	LEROY/EQUIVALENT PEN WEIGHT/TEMPLATE	EXAMPLE
1. Road and Street Names	1 Pen / 120 L Template	TOPEKA AVE
2. Alleys	0 Pen / 80 L Template	ALLEY
3. Parcel Number	1 Pen / 140 L Template	4
4. Original Lot Number	0 Pen / 120 L Template Slant	22
5. Creeks, Streams, Etc.	0 Pen / 120 L Template Slant	RYE CREEK
6. Rivers, Lakes, Etc.	1 Pen / 175 L Template Slant	KANSAS RIVER LAKE PERRY
7. Deed Dimensions	0 Pen / 100 L Template	100'
8. Scaled Dimensions	0 Pen / 100 L Template	105' (s)
9. Road Dimensions	0 Pen / 80 L Template	60' R/W
10. Deed Acreage	0 Pen / 100 L Template	40 Ac. (d)
11. Calculated Acreage	0 Pen / 100 L Template	44 Ac. (c)
12. Church, Cemetery, School Names Etc.	0 Pen / 80 L Template	SHAWNEE COUNTY COURTHOUSE
13. Ownership Block Number	2 Pen / 240 L Template	"04"
14. Original Block Number	2 Pen / 200 L Template	3
15. Transmission Lines	0 Pen / 80 L Template	K.P.&L. 100' R/W EASEMENT
16. See Note	0 Pen / 120 L Template	SEE 1" = 100' MAP 011-11-40
17. Easement Line	0 Pen	— — — — — — — —
18. Corner Dimension	0 Pen / 80 L Template	70
19. Adjoining Map Number	0 Pen / 120 L Template	011-12-10
20. Conflict	0 Pen / 120 L Template	CONFLICT
21. Map Numbers	2 Pen / 200 L Template	011-12-14
22. State Line	4 Pen	NEBRASKA KANSAS
23. County Line	4 Pen	SHAWNEE OSAGE

12.6 CONTINUED 1"=200', 1"=100' MAPS

SUBJECT	LEROY/ EQUIVALENT PEN WEIGHT/ TEMPLATE	EXAMPLE
24. Township and Range Lines	4 Pen	
25. Section Lines	3 Pen	
26. Quarter Section Lines	1 Pen	
27. Corporate Limit Lines		TOPEKA CITY LIMITS
28. Railroad R/W	1 Pen	A.T. & S.F. R.R. 100' R/W
29. Highway R/W	1 Pen	50' R/W
30. Property Boundary Lines	1 Pen	P/L P/L
31. Original Lot Lines	0 Pen	
32. Water	0 Pen	
33. Land Hooks	0 Pen	
34. Transmission Lines	0 Pen	
35. State Name	2 Pen/ 200 L Template	KANSAS
36. County Name	2 Pen/ 200 L Template	SHAWNEE COUNTY
37. Township and Range Number	1 Pen/ 140 L Template	T-22 S R-2 W T-23 S R-3 W
38. Section Number	1 Pen/ 140 L Template	2 1 11 12
39. Corporation Name	1 Pen/ 140 L Template	TOPEKA CITY LIMITS
40. Railroad Name	0 Pen/ 120 L Template Slant	*BURLINGTON N. R.R.*
41. Interstate Highway	0 Pen/ 140 L Template	70
42. U.S. Highway	0 Pen/ 140 L Template	24
43. State Highway	0 Pen/ 140 L Template	18
44. County Highway	0 Pen/ 140 L Template	136
45. S/D Limits	1 Pen	
45-A S/D Limit Number	0 Pen/ 80 L Template	2
46. Vacated Street	0 Pen	
47. Leasehold Imp. Boundary Lines	0 Pen	
48. Leasehold Improvement	1 Pen/ 140 L Template	13.01 L. I.
49. Mineral Rights	1 Pen/ 140 L Template	12 320 Ac. M.R.

12.7 PEN WEIGHT AND TEMPLATE GAUGE FOR 1"=400' MAPS

SUBJECT	LEROY/EQUIVALENT PEN WEIGHT/TEMPLATE	EXAMPLE
1. State Line	4 Pen	
2. County Line	4 Pen	
3. Township and Range Lines	4 Pen	
4. Section Lines	3 Pen	
5. Corporation Lines	3 Pen	
6. Railroad R/W	0 Pen	A.T. & S.F. R.R.
7. Highway R/W	1 Pen	60' R/W
8. Property Boundary Lines	1 Pen	
9. Original Lot Lines	0 Pen	P/L P/L
10. Water Line	0 Pen	
11. Land Hooks	0 Pen	
12. S/D Limits	1 Pen	
12-A S/D Limit Number	0 Pen/ 80L Template	2
13. Transmission Lines	0 Pen	
14. State Name	2 Pen/200L Template	KANSAS
15. County Name	2 Pen/200L Template	SHAWNEE COUNTY
16. Township and Range Number	1 Pen/140L Template	T-14S R-2E / T-15S R-2E
17. Section Number	1 Pen/140L Template	6 5 / 7 8
18. Corporation Name	1 Pen/ 140L Template	TOPEKA CITY LIMITS
19. Railroad Name	0 Pen/ 80L Template Slant	*BURLINGTON NORTHERN R.R.*
20. Interstate Highway	0 Pen/140L Template	70
21. U.S. Highway	0 Pen/140L Template	40
22. State Highway	0 Pen/140L Template	6
23. County Highway	0 Pen/140L Template	127

12.7 CONTINUED 1" = 400' MAPS

SUBJECT	LEROY/EQUIVALENT PEN WEIGHT/TEMPLATE	EXAMPLE
24. Road and Street Names	1 Pen/ 120 L Template	COUNTY ROAD
25. Alleys	0 Pen/ 80 L Template	ALLEY
26. Parcel Number	1 Pen/ 140 L Template	2
27. Original Lot Number	0 Pen/ 120 L Template Slant	20 21 22
28. Creeks, Streams Names	0 Pen/ 120 L Template Slant	DRAGOON CREEK
29. Rivers, Lakes Names	1 Pen/ 175 L Template Slant	CLINTON LAKE
30. Water Acreage	0 Pen/ 80 L Template Slant	35 AC. (c)
31. Deed Dimensions	0 Pen/ 80 L Template	175'
32. Scaled Dimensions	0 Pen/ 80 L Template	180' (s)
33. Deed Acreage	0 Pen/ 120 L Template	120 Ac. (d)
34. Calculated Acrege	0 Pen/ 120 L Template	127 Ac. (c)
35. Church, Cemetery, School, Etc.	0 Pen/ 80 L Template	SHILOH CEMETERY
36. Transmission Lines	0 Pen/ 80 L Template	K.P.&L. 100' R/W EASEMENT
37. Adjacent Map Reference	0 Pen/ 120 L Template	012
38. Easement Line	0 Pen	— — — — — — —
39. Map Number	2 Pen/ 200 L Template	012-04-10
40. Conflict	0 Pen/ 120 L Template	CONFLICT
41. Road Dimensions	0 Pen/ 80 L Template	60' R/W
42. Vacated Street	0 Pen	— — — — — — —
43. Leasehold Imp. Boundary Lines	0 Pen	
44. Leasehold Improvement	1 Pen/ 140 L Template	13.01 L. I.
45. Mineral Rights	1 Pen/ 140 L Template	12 320 Ac. M.R.

12.8 Parcel Number

Parcel numbers should be located in the upper right hand corner of parcels legally described by metes and bounds; however, the parcel number should be centered for platted lots. All parcel numbers should be parallel to the bottom of the map. When drafting consecutive parcels, all numbers should be kept in line. A pencil line can be used to draw guidelines. The parcel numbers should touch this line. After parcel numbers have been added, this pencil line can easily be erased.

12.9 Original Lots

Original lot lines are represented by short ticks. The ticks should be approximately one quarter of an inch long. Original lot numbers should be centered near the rear of the lot. Should a property line prevent this, the lot number can be moved up or down. A guideline should be used to keep the lot numbers in line. The lot numbers should be drafted parallel to the lot line.

12.10 Churches, Schools, and the Like

All identifying landmarks should be shown by name, when known. No symbols should be used. Names of these landmarks should be drafted parallel to the bottom where possible.

12.11 Acreage

The acreage should be centered under the parcel number and should read parallel to the bottom of the map sheet. If a parcel has both a deed acreage and calculated acreage, the deed acreage should be shown on top with a small (d) following it. The calculated acreage should be centered under deed acreage with a small (c) following it.

12.12 Dimensions

On all parcels requiring dimensions, the dimensions should be located in the center of the length of the line. When both a deed dimension and a scaled dimension are necessary, the deed dimension should be shown first with a small (d) after it, followed by the scaled dimension with a small (s).

On 1" = 400' maps, when the parcel has the same rear dimension as the front dimension, and each side dimension is the same, only the front dimension and one side dimension are necessary.

On 1" = 100' maps, when consecutive lots of the same size are being dimensioned, all front dimensions should be shown along with the first and last side dimensions.

12.13 Block Numbers

The ownership or map block number should be located near the center of each block. Each number should be drafted to read parallel with the bottom of the map. The original block number from the subdivision plat should be dashed.

12.14 Subdivision Boundary Ticks

Subdivision ticks are used to show the boundary of each subdivision on the map. Ticks should be placed at all major corners of each subdivision on the map and numbered. The number is then placed in the appropriate space in the subdivision index on the border of the map sheet.

12.15 Land Hook

When the land hook can be shown perpendicular to the object it crosses, it should be so drawn. Each side should be approximately the same length. The angle of the hook should be approximately thirty degrees and should point counterclockwise. Dashed land hooks will be used across division lines to denote separate parcels, but same ownership. Solid land hooks are used to denote same ownership, same parcel across roads, creeks, and so on.

12.16 "See Notes"

"See notes" are used to show that a portion of the map is being mapped at another scale. On 1" = 400' maps, reference to 1" = 100' and 1" = 200' maps should be shown. The scale and the map number should be shown.

12.17 Conflicts

When there is a conflict of ownership, the conflicting property lines should be dashed instead of solid, and the word "conflict" should be written within the property in question.

12.18 Subdivision Names

All subdivision names, along with the plat book and page number, should be shown along with a numerical listing in the subdivision index on the map border. The corresponding numbers should be placed inside the subdivision boundary ticks on that portion of the map that it applies to.

Phase 13 – Final Ownership Index Cards

The requirement for the final ownership index card has been deleted. In lieu of the index card, the contractor may supply an industry standard data processing tape containing an alphabetical listing of the property owner's name and address, and the legal description. The tape shall be compatible with the data processing equipment in the county.

Phase 14 – Ownership Map Maintenance

The contractor shall provide continuing maintenance on the completed property ownership maps for each new real property transfer recorded up to ______ days prior to final delivery date.

14.1 The county shall supply to the company, monthly, copies of all newly recorded documents affecting ownership of any real property situated in the county after the date of the contract signing, up to ____________ , 19______. The new records shall consist of and include the following items:

14.1.1 A copy of the entire title instrument involved in each transfer; that is, the recorded deeds, wills, and so on

14.1.2 Copies of any new maps, subdivision plans, and survey or deed plots involved in the transfer

14.1.3 Copies of any new rights-of-way plans or acquisitions of additional rights-of-way

14.1.4 Copies of any ordinances of street or alley closings and any annexations by cities or changes in any political district lines by any agency or entity in the county

14.1.5 The property transfers, subdivision, or consolidation

14.1.6 Each shipment of deed copies, plats, surveys, right-of-way plans, and so on shall be accompanied by a transmittal form provided by the county. The transmittal form shall indicate the material or data being shipped, inclusive dates of the shipment, and inclusive book and page numbers where deed copies are involved. A copy of the transmittal shall be retained by the county for future reference and verification that all data and material shipped were processed properly by the company.

14.2 The company shall update the new and completed ownership maps, including the work card files, at least monthly during the contract mapping period.

14.2.1 The company shall, on receipt of the first shipment of data or material from the county, provide a register of maintenance for all items received during the ownership map maintenance period of the contract. This register shall be maintained in chronological order continuously throughout the maintenance period indicating the following:

1. Deed books and page number
2. Grantor's last name(s) and grantee's last name(s)
3. Type of instrument
4. Map and parcel number
5. Notes column indicating any unusual circumstances encountered

14.2.2 The register of maintenance shall be checked and all items verified by the company and the county prior to final delivery and acceptance.

Note: The company's maintenance procedure shall be subject to inspection and approval by the county and the director of the Division of Property Valuation.

Phase 15 – Edit and Inspection

The contractor, county, and state shall continuously edit and inspect all ownership maps, indexes to the maps, and all other work until the project has been completed. The contractor's edit and inspection shall be conducted by their most *qualified*, *experienced*, and *competent* senior ownership mapping technicians.

Each mapped parcel shall be reviewed for accuracy, neatness, and completeness. Any errors, omissions, and discrepancies discovered shall be corrected prior to final delivery to the county and final approval by the director of the Division of Property Valuation.

Phase 16—Inspection and Approval by the County

Any and all items created under the terms of the contract agreement and these technical specifications are subject to inspection and approval by the county and the director of the Division of Property Valuation. Upon delivery to the county of any and all items as prescribed in the contract agreement and these technical specifications, the county and the director of the Division of Property Valuation shall conduct a complete and thorough review of the quality, quantity, completeness, accuracy, and neatness of the items.

During the period of this review, the county and the Director of the Division of Property Valuation shall prepare a listing of any errors, omissions or discrepancies that may be discovered. Upon completion of the inspection, the county shall return to the contractor any and all items as it may deem necessary together with said listing of errors or types of errors, omissions, or discrepancies noted for correction by the contractor. A copy of each list of errors, noted for correction by the contractor, will be retained by the county for future verification that proper disposition was made on each listing.

Upon receipt of the returned items and a listing of the errors, omissions and discrepancies, the contractor shall take prompt corrective action in an effort to cure or resolve them as required to comply with the terms of the contract agreement and these technical specifications.

Summary of Items to Be Delivered by the Contractor

1. All aerial photography products used in the preparation of the property ownership maps
2. The film positive photo screened enlargements as outlined and prepared under the technical specifications or where provided by the county
3. One complete set of final ownership maps in map number order, index maps, and title sheets on 4 mil, dimensionally stable, double-matte polyester film material as outlined by the specifications
4. All work map overlays created for each final map sheets in map number order
5. Two sets of quality diazo paper prints of each ownership map, two diazo prints each of the index map screened enlargement and two composite prints of each screened enlargement and the ownership map, all prints delivered in map number order
6. Any computer tapes or other items created
7. All reports and errata lists as required by the technical specifications
8. Map work cards containing assessment roll information and ownership information arranged by map and parcel number
9. Any and all maps, plats, plans, microfilm, or other information obtained or produced in order to complete this project (all map related items of material will have the map reference number shown and will be sorted in map number order prior to delivery to the county)
10. One negative and two positive copies of 35mm microfilm of all ownership maps
11. A minimum of 10 percent of the total number of map sheets in blank mylars with the border, title block, and legend along with the original master mylar overlay
12. Extra blank map work cards equal to at least 10 percent of the county's total final parcel count
13. Register of maintenance items as provided for in Phase 14

Summary of Items Furnished by the County

1. A monthly report of all new transfers of ownership of any real property situated in the county after the date of the signing of the contract; all deed copies of real property transfers recorded after the last assessing date or closing of the land rolls and prior to the signing of the contract should also be provided, the deed record copy to include the entire deed in a hard copy form (Xerox or photostat)
2. The access to and the use of the county's records room, or rooms, during normal office hours for the microfilming or the duplication of any existing microfilm, or the copying by other means, of any necessary deeds or recorded maps which the contractor and the county agree are necessary for its particular method of preparing the new ownership maps
3. Access to and use of available source maps that would assist in determining a property's ownership, location, boundary, and limits, including a copy of all existing plats or old tax maps

4. Complete cooperation of the county, city, and town officials relative to matters pertaining to the performance and completion of the ownership mapping program

5. A transmittal file for tracking all items provided to the contractor during the entire contract period

A Suggested Schedule of Mapping Progress

Mapping Phase	Approximate Phase Dates	Number of Months
1. A. Aerial photography B. Edit and review	_______ TO _______	___________
2. County recorded records A. Research B. Microfilm C. Copying	_______ TO _______	___________
3. Source document collection	_______ TO _______	___________
4. Work card preparation	_______ TO _______	___________
5. Layout and design A. Original survey B. Right-of-way C. Sub/plat D. Edit/Supervision	_______ TO _______	___________
6. Preliminary map assembly	_______ TO _______	___________
7. Area calculations	_______ TO _______	___________
8. Dimensions	_______ TO _______	___________
9. Permanent map and parcel numbering	_______ TO _______	___________
10. Field edits, errata lists, and conflicting ownerships	_______ TO _______	___________
11. Final map sheets	_______ TO _______	___________
12. Final map A. Drafting B. Edit/Supervision	_______ TO _______	___________
13. Index card/data processing tape	_______ TO _______	___________
14. Ownership map maintenance	_______ TO _______	___________
15. Edit and inspection	_______ TO _______	___________
16. County acceptance	_______ TO _______	___________

Mapping Progress Billing Schedule

Mapping Phase	Phase Fee	Percent of Total
1. A. Aerial photography (enlargement or reproduction)* edit and review B. Edit and review		
2. County recorded records A. Research B. Microfilm C. Copying		
3. Source document collection		
4. Work index card preparation		
5. Layout and design A. Original survey B. Right-of-way C. Sub/plat D. Edit/Supervision		
6. Preliminary map assembly		
7. Area calculation		
8. Dimensions		
9. Permanent map and parcel numbering		
10. Field edits, errata lists, and dual ownership		
11. Final map sheets title block and legend		
12. Final map A. Drafting B. Edit/Supervision		
13. Index card/data processing tape		
14. Ownership map maintenance		
15. Edit and inspection		
16. County acceptance		

Note: All persons or firms submitting proposals will be required to price and list the phase fee items above in order that the county may evaluate the person's or firm's experience and the methods to be used in preparing new ownership maps according to the technical specifications.

* where applicable.

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20 STANDARDS AND SPECIFICATIONS FOR AN AUTOMATED MPLIS

Steve Ventura

INTRODUCTION

Perhaps it is a sign of technological maturity -- the call for standards in land and geographic information systems (LIS/GIS) now comes from many quarters. A few innovators can no longer go their own way. As billions of dollars are invested in systems and data, the penalties for closed systems and undocumented data bases and procedures become apparent. Cost-effective operation of systems and access to current and reliable information increasingly depends on the ability to transfer, evaluate, and document data resources and system capabilities. These will depend on the development, adoption, and compliance with several types of standards, and on the ability to carefully specify system components to meet the requirements of a jurisdiction. The previous chapter detailed the standards and specifications that pertain to the basic data components of an MPLIS, particularly base maps and related data sources to produce base maps. This chapter provides an overview of the standards that apply to an automated system and an introduction to the procurement process.

STANDARDS

This section of the chapter provides an overview of standards, particularly as they relate to local land information systems. It is divided into four sections: the need for standards; standards applicable to LIS/GIS; challenges in the development, implementation, and enforcement of standards; and future needs and trends.

THE NEED FOR STANDARDS

The benefits of standards do not come from the standards *per se*. In fact, it typically requires additional effort to learn and apply appropriate standards. The benefits come from what standards

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standards support -- the activities or tasks that would be more difficult, time-consuming, or incorrect without standards, such as sharing data with other organizations or training new personnel.

Most benefits from LIS/GIS in terms of services and decision-making depend on accurate, accessible, and current data. Data automation and maintenance are major components of system cost, ranging from 40 to 80 percent of total system costs by various estimates. These tenets should be quite familiar to system developers and managers. It should also be apparent that data exchange -- sharing, selling, swapping, whatever -- can, and in most cases should, be an important mechanism to acquire useful data at a reasonable cost. Because geographic data are usually held by public agencies, their cost is generally reasonable. A second user pays for the marginal cost of reproduction on the assumption that taxpayers have already paid once for the data.

Successful data exchange requires much more than the transfer of a bundle of bits and bytes. The data need to be on a media and in a form that can be used by the recipient, and there needs to be information about what the bundle contains (e.g., what area does it cover, how was it created, how is it organized, how accurate is it, and so forth). If, because of the lack of standards, it is necessary to decode data and develop conversion routines, the cost may be equal to or even exceed the cost of automating data from source material. Conversion routines often involve special programming, an expensive proposition. And, programming typically only deals with the common cases of a conversion process. The costs to deal with the special cases and anomalies can mount rapidly.

The number of agencies that have some kind of automated spatial data is only going to increase. Technical limitations in efficiently moving data from one place to another are being solved, assisted by data transfer standards as well as some related telecommunications and hardware standards. However, questions such as who has what data, how to get access to them, and how good they are will continue to be challenging problems. Their resolution involves data quality standards and data documentation, also known as "metadata," which describe what a data file or data base contain. This kind of documentation can also be valuable within an organization. For example, it can save time during personnel transitions, especially for organizations that have only one or two people dedicated to a system. Data documentation may also be useful if the validity of data in a system is challenged.

At the present time, most *ad hoc* data exchange takes place under the sales principle of *caveat emptor* -- let the buyer beware. A data provider is not obliged to guarantee that data will be useful for another agency's purposes. However, for a recipient agency to know if it is worth the effort to obtain data from a provider, they need information about data quality to conduct a "fitness for use" evaluation. It will make the data evaluation efforts of agencies easier if and when there are generally accepted data quality standards and reporting procedures. This is particularly true for agencies that must integrate data from a number of different sources, such as planning agencies.

Successful data transfer ultimately depends on agency policies and institutional agreements as well -- data access and cost recovery "standards" that describe how agencies provide their data. Such standards are the crux of legal, economic, and philosophical arguments that the LIS/GIS community is embroiled in currently. It is likely to be many years before there is a pervasive legal interpretation of the Freedom of Information Act and corresponding state open records laws. The rapid emergence of LIS/GIS is one of the functions forcing courts and legislatures to create law dealing with access to publicly held digital data. Such legal standards are needed to "level the playing field" between agencies, and to provide clear signals about related issues such as cost recovery and private profit from data collected for public purposes.

STANDARDS APPLICABLE TO LIS/GIS

At least four classes of standards apply to LIS/GIS -- application standards, data standards, information technology standards, and education and training (professional) standards. All LIS/GIS implementations must account for many application-specific and professional standards -- standards that pertain primarily to the *use* of geographic data for particular purposes, not to its generic creation, maintenance, and transfer. It would be impossible to try to describe the entire gamut of application-specific standards, so they are only briefly discussed.

Some standards are common to all land and geographic information systems. Since geographic *data* are so fundamental to LIS/GIS, this section presents three data-related standards that will need to be considered -- data transfer, data quality, and data documentation. Another type of standards -- computing and information technology standards that pertain to computer architectures, networks, user interfaces, data base queries, data storage and display, and so forth -- must be considered with any automated information system, and so are briefly described.

Finally, the question as to whether the LIS/GIS community needs standards about the education or training of GIS specialists or the accreditation of academic institutions is also considered. No such standards currently exist. Though the need for such standards is frequently raised, their creation and enforcement is problematic.

Application Standards

Since the range of applications of LIS/GIS is almost limitless, the types of standards that have some bearing on GIS use are likewise almost limitless. Application standards may come from specific legal requirements (e.g., official state coordinate systems), from professional associations (e.g., the American Society for Photogrammetry and Remote Sensing's (ASPRS) spatial accuracy standard), or from agencies that have substantial influence in an application area (e.g., the U.S. Environmental Protection Agency's "Locational Data Policy").

A good example of professional association standards is the "GIS Guidelines for Assessors" (IAAO/URISA, 1992), which was written by two professional associations. It provides a good summary of application standards and procedures for local land records systems, many based on federal and industry standards and commonly accepted professional practices.

Many disciplines that contribute to LIS/GIS have professional and ethical standards. Geodetic, surveying, and mapping standards provide the underpinnings of spatial data. Standards are rooted in the education and training of professionals in these disciplines. These fundamental principles are typically supported by specific procedures, documents, or numeric standards. For example, cartographic projections have been standardized in a library of software routines (General Cartographic Transformation Package) developed and distributed by the U.S. Geological Survey (USGS). The code or the algorithms are incorporated in many commercial GIS packages. As another example, the National Geodetic Survey has facilitated the transition to a new standard, the North American Datum of 1983 (NAD 83) by distributing reference point coordinates in the new datum and developing software (NADCON) to transform from the old datum to the new one (NADCON).

Data Standards

Data Transfer Standards

The concept and purpose of a data transfer standard is very straightforward -- it is a means to convey spatial data from one organization to another. In its simplest form, a transfer standard is simply a common data format that proprietary systems can use as an intermediate to convert to other data formats (Figure 20-1). An example is the Digital Line Graph (DLG), a data transfer format developed by USGS. A more complete data transfer standard will include additional information about the data, such as lineage and data quality, and a standard set of spatial objects and classification methods. The recently adopted Spatial Data Transfer Specification (SDTS) (i.e. FIPS - 173) is an attempt to provide a complete set of tools for spatial data transfer.

Unfortunately, the development and implementation of transfer standards are not as simple as the concepts. The wide variety of spatial data formats, structures, and applications, along with a plethora of hardware and software systems, has resulted in a number of methods for data transfer. In addition to official standards such as DLG or SDTS, there are any number of default or *ad hoc* methods. These are essentially methods that two or more parties have found that work to transfer data. They are often based on data structures of proprietary software, such as Environmental Systems Research Institute's "Arc Export™" or Autodesk's "AutoCad DXF™" formats. Though these default or community-based methods can work well for conveying data when all parties understand what is contained in the data sets, there are problems. These include loss of information in the conversion process, lack of the ability to convey metadata, and exclusion of potential participants who don't have the capability to use the proprietary format.

Though the GIS/LIS community does not yet have one data transfer standard that works for all conditions, there are some attributes of a data transfer standard (DTS) that most agree on:

- a DTS should not lose or in any way degrade information content;
- a DTS should be independent of hardware, software, and media;

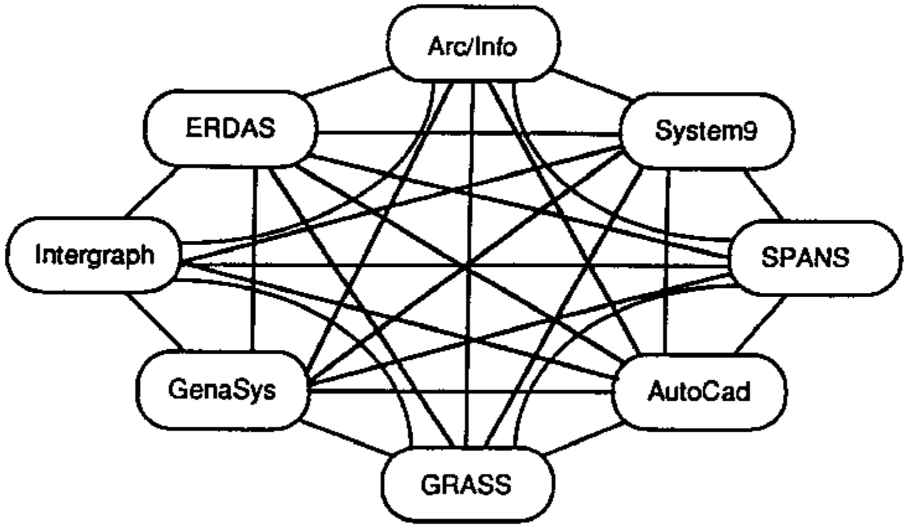

Figure 1.a **N to N data conversion** - without a common transfer format, each software system must write convertors to and from each other system. For these eight packages, this would result in a 8 systems X 14 conversion routines, or 112 different conversion programs!.

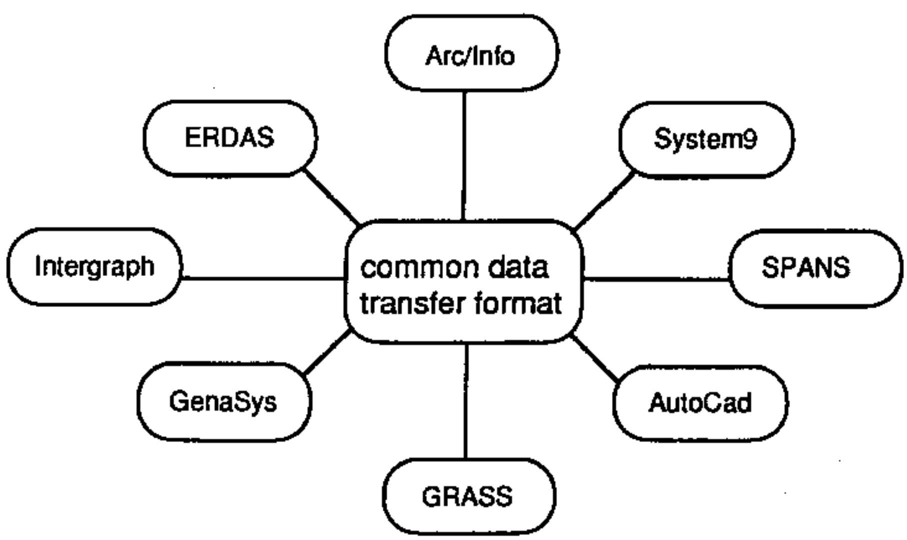

Figure 1.b **Data conversion through a common format** - with a common transfer format, each software system write convertors only to and from the standard. For these eight packages, this would result in a 8 systems X 2 conversion routines (from and to), or 16 different conversion programs!

Figure 20-1: Concept of a Data Transfer Format

- a DTS should support common geographic data types (e.g., raster, vector) and common data models (e.g., relational, feature-based);
- a DTS should transfer non-spatial (attribute) data and metadata;
- a DTS should be well documented and unambiguous;
- a DTS should be compatible with existing standards;
- a DTS should be easy to understand and implement;
- a DTS should be acceptable to users.

Data Quality Standards

Digital spatial data are a representation of some physical phenomena (e.g., roads or rivers) or logical constructs (e.g., property or jurisdictions). Like maps, our ability to encode information about these phenomena or constructs is limited by the tools and techniques available for measuring, describing, and recording. For example, surveying instruments used for original data capture have inherent limitations in the precision of locational data they produce, whether the data are recorded in the form of bearings and distances, maps, or coordinates in a GIS. Likewise, our ability to interpret land use types from aerial photography or satellite imagery depends on scale and resolution. Subsequent processing of data -- transfers, conversions, transformations, aggregations, and so forth -- can also affect reliability.

Everyone wants current, complete, and accurate data for their applications. Information reduces uncertainty, so better information reduces uncertainty more certainly. But, it is never possible to have completely accurate information, particularly at a reasonable price. Organizations vary in their requirements concerning accuracy, currency, completeness, and other measures of data quality, and in their willingness to pay for improvements. Even within organizations, the requirements for different applications may vary widely. As a result, it isn't possible to define a single "quality standard," such as a numeric accuracy threshold.

Instead, the concept of a "data quality report" is used to convey what is known about data quality. Specific quantitative or qualitative evaluations, such as the National Map Accuracy Standard, may be included in a data quality report to convey particular aspects of data quality (in this case -- positional accuracy). Elements of a data quality report for digital spatial data are described briefly in Table 20-1.

An organization must have a means of assessing how good data are for their applications, whether produced themselves or obtained from other organizations. This is what is meant by a *fitness for use* evaluation, as suggested by Chrisman and others (NCDCDS 1987). An organization must determine whether data are suitable for their purposes using measurable or observable aspects of data quality. Standard criteria and procedures for "fitness for use" evaluation are not available.

Spatial accuracy -- the position of well-identified features should be compared to a source of higher accuracy.

Attribute accuracy -- the described characteristics of geographic objects should be correct, complete, and current.

Logical consistency --the spatial relations such as adjacency and connectivity between data elements (topology) should be correctly described.

Completeness -- every object should be represented once and only once in both spatial and attribute data.

Lineage - Data sources and subsequent processing should be described, along with relevant information such as transformation control points or modeling assumptions.

Table 20-1: Elements of a data quality report (as originally recommended by the National Committee for Digital Cartographic Data Standards, and now incorporated in SDTS).

Spatial Metadata

The term "metadata" has come to mean data about data -- descriptions of what a data set or data base contains, how it is organized and formatted, how it can be accessed, and so forth. Metadata typically includes data quality and data transfer-related information. As suggested by Robert F. Gurda (Wisconsin State Cartographer's Office):

> *"A robust metadata system would assist in reducing duplication, clarifying custodianship, reducing misuse of data, and alleviating custodians of some of the time needed to respond to requests for information."*

Metadata may be recorded for three purposes. The first purpose is essentially "data cataloging" -- providing an overview and summary of the contents and quality of data sets or bases. This level of metadata is analogous to a card catalog in a library which contains a very brief synopsis of the contents of volumes and information about how to find the material. Within an organization, data cataloging provides an inventory of spatial data. For someone else seeking information, it provides for "browsing" -- the ability to quickly determine whether data are potentially useful and so worth seeking further information.

A second purpose for metadata is to facilitate data sharing. Metadata consists of information about form, content, and quality needed to convey and use data sets or bases. Without such information, data transfer may entail repeated trials and errors. This type of metadata includes some of the elements listed below as part of internal documentation -- enough to provide "full disclosure," but not so much as to overwhelm secondary users with useless detail.

The third type of metadata is for internal documentation -- keeping track of what a data set or base contains and how it is organized, maintained, and updated. This is the most detailed type of metadata. It will include elements of the previous two levels, plus more detail on the internal structure and organization of data sets and data bases. It can include such things as:

- data dictionaries -- descriptions of the form and content of data sets within a data base, including meanings of codes and classifications;

- organization -- relationships among and between data elements and sets;

- tiling systems and other geographically related means for organizing data;

- procedures used to automate, manage, update, data elements and data sets;

- data flows -- how do data move within and between departments or data storage locations;

- "trigger" events and transactions that precipitate updates and data flows;

- authorization for access to and dissemination of data;
- standards used in any aspect of data processing;
- lineage -- any changes in form or format that data undergo; and
- archival records -- purpose, form, location, frequency, etc.

At present, there are not yet any official FIPS standards for metadata. However, there is widespread recognition of the need for standards and procedures at many levels within the LIS/GIS community. Several organizations have or are developing their own methods (e.g., Vrana, 1992). The library community has contributed many good ideas, particularly in regard to cataloging and remote access. At the national level, the Federal Geographic Data Committee (FGDC) released a draft metadata standard in June 1994. This standard is primarily oriented toward metadata requirements to support data transfer, though it may also serve internal documentation needs. After evaluation and modifications, it will be proposed as a federal information processing standard. Even though this process is not complete, organizations can still realized many of the benefits of Metadata standards by using the draft standard, developing their own procedures and documentation, or adapting another organizations.

Information Technology Standards

With the vast variety of computer hardware and software on the market today, it is seemingly a miracle that any data moves between organizations. That we can is a tribute to the existence of information technology (IT) standards, also known as computing standards. For the most part, these are standards that come from the computing industry. Creators of hardware and software are seemingly well ahead of the LIS/GIS community in the adoption and use of standards for a variety of purposes, including telecommunications, user interfaces, graphic interfaces, system inter-operability, data base queries, and so forth. This is not to suggest that all the problems have been solved. We will undoubtedly continue to have problems with incompatibility, but hopefully solutions or work-arounds will be easy or inexpensive.

Most of the IT standards that affect LIS/GIS arise directly from general computing. The Federal Interagency Coordinating Committee on Digital Cartography (Guptill 1989) compiled an annotated list of applicable standards adopted by the federal government as Federal Information Processing Standards (FIPS). Other standards arise directly from the computing industry that have not yet been adopted as FIPS. Consortia of vendors, sometimes in conjunction with agencies or academia, have developed and adopted standards in areas such as user interfaces (e.g., Windows, AIX), network operations (e.g., TCP/IP, FDDI), system interconnections (e.g., OSI/Motif), data base queries (e.g., SQL), and display and plotting methods (e.g., CGM, TIF) (Exler 1990).

NIST is testing several extensions of information technology standards in a LIS/GIS context (Tom 1990). Such extensions will ultimately be critical to further standard development in other aspects of LIS/GIS, such as metadata. However, IT standards generally are not unique to LIS/GIS, and so are not discussed in any more detail herein.

Education and Training Standards

As technologies mature, an interest or need to certify potential employees or consultants who profess to be skilled in the technology typically develops. For example, in fields related to LIS/GIS, photogrammetrists are certified by a professional organization (ASPRS) and surveyors are typically registered by state boards upon proof of competency. Many employers have expressed interest in some kind of proof of LIS/GIS skills, and students from good academic or training programs may want a means to tout their competency. With such standards, employers could hire prospective employees with greater confidence, or at least with the knowledge that prospective employees had been exposed to particular concepts and procedures. Accreditation of academic programs or institutions could also provide prospective students with information to guide their selection of schools.

Currently, no form of standards for LIS/GIS skills or competency exists. There are at least three possibilities for such standards:

- licensing based on education, experience, and/or skills testing;
- certification based on completion of specific courses or training; and
- accreditation of academic programs.

Each of these approaches has significant drawbacks, arising because 1) the "core" skills and knowledge of LIS/GIS are poorly defined, and the applications are extremely broad; 2) there is no single professional organization which represents all aspects of LIS/GIS; and 3) the demand for employees is quite high, and so compliance with standards by employers and usefulness of standards to potential employees is doubtful. (See Obermeyer (1992) for a more complete discussion of the pros and cons of certification.

LIS/GIS professionals within certain application areas could still seek some sort of education and training standards, in spite of the previously listed impediments. LIS/GIS skills could be an extension of existing certification or licensing. For example, planners' certifications or surveyors' licenses could have an optional notation attesting to LIS/GIS competency based upon successful completion of an additional section of testing about LIS/GIS in those fields.

Graduates of academic or training institutions may find it useful to have the completion of LIS/GIS related course work recognized through minors, certificates, or even new majors and graduate degrees. Though this does not constitute a standard, at least students would have the institution's standing behind their claim of competency. Several colleges and two-year technical centers have developed degree programs with GIS in the title. Again, there is not a single organization with the mandate and capacity to accredit academic institutions at the present time.

PROBLEMS AND CHALLENGES IN THE DEVELOPMENT, IMPLEMENTATION, AND ENFORCEMENT OF STANDARDS

The benefits of standards do not come without effort or cost. Particularly in relation to data sharing, the benefits of standards only accrue when they are widely adopted and practiced. A related challenge is enforcement. It is not sufficient for the top level of an organization to declare that standards will be followed; these must become incorporated into the working routines throughout an organization. This may entail costs such as retraining or re-tooling. In addition, critics suggest that standards may suppress innovation, may limit the use of inherent hardware or software capabilities, or may compromise system security. This section provides an overview of these challenges and problems, along with some potential solutions.

Development

The development of standards is essentially a process of developing consensus among diverse and diffuse groups. Almost everyone has ideas about what is right, and organizations with significant investment in an existing system are interested in promoting *their* solutions. Although standards are in everyone's best interest, it is no one's job in particular to develop them.

These barriers have been apparent in the development of IT standards. Standards have been developed only after a couple decades of competing and incompatible solutions -- after the market demand for compatibility and inter-operability became very strong, after heterogeneous computing environments became common, and after the market was large enough to assure a niche for most vendors.

Development of standards for LIS/GIS is particularly problematic because it has been largely a public sector technology. NIST is the only organization with a mandate to develop standards; it only recently addressed GIS. Few public employees are given leave to work on standards development committees, and resources committed for development are limited and readily rescinded. The results are sporadic development, often without representation from potentially affected sectors. For example, SDTS has been criticized as inadequate for local land information. It was difficult for local government to be represented in the development of SDTS for logistic and monetary reasons, as well as a federal law specifically prohibiting membership of non-federal employees on certain kinds of committees. It is a tribute to several forward thinking individuals in federal agencies and academia that LIS/GIS standards have been proposed in spite of these obstacles.

Perhaps the most difficult part of standards development is testing and refining. This requires the participation of willing organizations with the resources to adopt a standard and report on their experience. They may test a standard knowing more changes may be necessary when the final version is developed. In other words, it is not a trivial undertaking. The only apparent advantage is getting a jump on the benefits of using standards. However, in the case of data sharing, these won't accrue until other organizations adopt the standards as well! It may be necessary for the federal government to buy the help of local agencies if they are committed to testing standards that will work at the local level.

Adoption, Compliance, and Enforcement

It should go without saying that standards are only useful if they are standard -- if they are widely adopted and used, and if they are interpreted and executed the same way. *Adoption* is essentially a public relations challenge -- information about the existence, implementation, and benefits must be widely available.

Ultimately, it is necessary for professional organizations and national agencies to sell a vision of collective benefits. Organizations, particularly at the local level, may not find an attractive benefit-to-cost ratio from a narrow evaluation of standards. They must be convinced that there are broader societal benefits, and perhaps long-term or unanticipated benefits that will accrue to their agency.

Professional groups such as URISA, ASPRS, ACSM, AAG, and AM/FM have been instrumental in disseminating information about LIS/GIS standards. However, they usually only publicize general information about the standards, not why and how they will work for particular organizations. Federal entities with a mandate to promote standards (e.g., FGDC and NIST) have helped to some extent with this chore. Agencies with extensive data distribution obligations (e.g., USGS and Bureau of the Census) have made important contributions by implementing and testing standards from their perspective.

Unfortunately, some good standards development activities also take place that have not received broad review and testing. For example, the USGS Water Resources Division and the American Society for Testing and Materials are leading an effort to develop standards for hydrology-related GIS data which is little known outside of narrow professional circles, though it is potentially broadly applicable. Likewise, the IAAO/URISA guidelines for local assessors may be very important for a number of local land records activities, but the guidelines are as yet little known.

Compliance is essentially the technical side of adoption -- can an organization develop procedures and use software programs that adhere to the standard. Compliance with LIS/GIS-related standards often depends to a large extent on software vendors, even though standards may have been developed in the public sector. Very few organizations have the resources to do extensive GIS programming, therefore they must depend on software companies to incorporate the standard. Reliance on vendors' interpretations and implementations of standards can be a problem, particularly for very broad standards with a great deal of flexibility, such as SDTS. Vendors' interpretations may be so different from each other that they are partially incompatible. The use of "profiles" -- well-publicized and documented interpretations of SDTS for particular application areas -- has been suggested as a way to prevent this problem, but profiles must still be implemented by each vendor.

System implementors would find it very useful to have some assurance that commercial software complied with standards. This would require an independent organization to develop and report on benchmarks and tests. Such certification of complete and correct implementation could be from a federal agency, a professional society, a consortium of vendors, or some combination.

Though our notion of standards is largely based on voluntary compliance, a case can be made for active *enforcement* in some circumstances, particularly when collective benefits clearly outweigh cumulative individual costs. The federal government is a good example of a situation where sanctions and budgetary constraints could be used to enforce standards. To some extent federal agencies are compelled to use standards through mechanisms such as the Office of Management and Budget's directives about mapping and spatial data (Circulars A-16 and A-130). However, enforcement of some standards, such as the NAD 83, is lax -- although not quite as bad as the metric standard adopted by the United States in the late 1970s. But, NAD 83 has not as yet been adopted widely enough to derive benefits from a common and more accurate system and force its use in agencies that deal with federal agencies.

Enforcement of standards can also take place through incentives; in particular, reimbursement for "appropriate" activities. For example, the Wisconsin Land Information Program provides grants-in-aid for local land records modernization. Grant criteria specifically require use of appropriate standards.

Direct Costs of Implementation

The costs of standards' implementation include retooling -- new software or equipment, training, modification of applications and procedures, and replacement of existing stock. With careful planning and incremental adoption, many of these costs can be minimized.

Software upgrades to comply with a standard typically will be covered under existing software service agreements or will be part of the next major "release" of software. Costs above and beyond ordinary software costs are likely only when additional programming is necessary to meet specific needs. It would be somewhat unusual to incur equipment costs to meet LIS/GIS standards. One possible circumstance is where data entry equipment such as digitizers or scanners are not sufficiently accurate to meet a spatial accuracy standard; in this case, they probably should have been replaced anyway.

Developing new procedures, such as those required for tracking metadata, can incur significant costs, as can teaching staff to use them. The implementation process entails development and testing of procedures, and may also include re-programming parts of applications. Most GIS software vendors provide a "toolbox" -- a library of basic software functions -- which must be customized for particular circumstances using "macro languages" and other programming tools. Programming is rarely cheap, and may be particularly difficult for broad and flexible standards such as SDTS, where application programmers must figure out which and how small portions of the standard apply to their situation. Again, the widespread sharing of profiles and templates can mitigate this problem.

Costs can be extraordinary when a new standard requires replacement or modification of existing documents or records. For example, the adoption of a new parcel identification numbering scheme could involve many hundreds of hours in an average size county, whether changes are made by erasing existing numbers on paper (or mylar or linen) maps or re-keying computer records. The Southeastern Wisconsin Regional Planning Commission estimated that it would take about six million dollars to convert their existing maps to NAD 83.

If wholly adopting standards requires such enormous costs, it may be possible to use them on a "day-forward" or "as-needed" basis. In the example of an existing set of maps built on NAD 27, new mapping can be done on the new datum in order to work toward eventual compatibility with others and to take full advantage of the Global Positioning System (GPS) -- (a satellite based surveying system which is compatible with NAD 83). The location or coordinates of features on the old datum can still be shown to ensure compatibility with existing documents. For other kinds of records, such as parcel identifiers, it may be easier to use the standard-based system for digital data sharing, but keep the existing system on existing hard copy products. This is the tactic taken by many Wisconsin counties that must comply with a standard of the Wisconsin Land Information Program. By building a cross-reference index between old and new systems, they can provide parcel data based on the State's numbering system, without disrupting their current procedures or documents.

Hidden Costs of Standards

In a very limited set of circumstances, there may be some less obvious costs associated with standards. For most organizations, benefits will far outweigh these potential costs.

In early stages of technology development, it is often feared that early development of standards will suppress innovation. But since very few organizations are developing the core components of GIS, this is not a likely problem. Research and development organizations generally understand the implications of standards, and have learned to use or not use them as appropriate.

What may occur in many organizations though, is the suppression of *adoption* of LIS/GIS through overly rigorous enforcement of standards. Potential new users may not change to automated methods because they are constrained from pursuing a solution suited to their application. For example, a data processing department may only wish to support one brand of GIS software (and may have the power through budget oversight to prevent any other software from being purchased). The selected software may not be adequate for some departments. That department will be forced to abandon their automation goals, ignore the standard, or adopt a sub-optimal solution. On the other hand, enforcement of some standards, particularly data-related standards, can provide substantial collective benefits. It is a significant challenge for those guiding land records modernization to find an appropriate balance between rampant adoption throughout an organization with little coordination or standardization, and suppression of adoption through inappropriate or overly rigorous standards.

Some information technology standards may limit the full use of computer or software capabilities. By using standardized interfaces and operating systems, and by adhering to the notion of device independent programming (software that will run on multiple kinds of computers), developers may sacrifice some of the performance optimization that is achieved by using capability "hard-wired" into specific machines. This small loss in speed or capability is unlikely to affect most land and geographic information systems, since few operations are limited by computing power. To the contrary, most operations cannot yet take full advantage of interconnectivity of systems and data bases, because there is not yet a spatial equivalent or extension of the Standard Query Language.

A final note of caution on problems with standards -- standardization of operating systems and networks may have system security implications. Access methods will be known, offering routes for hackers, viruses, and so forth. The computing industry always tries to stay one step ahead of trouble-makers, but it is a battle that is never completely won. Standard organizational procedures can sometimes make it obvious when unauthorized access is being attempted. Ultimately, the best defense is a good system backup process, so that data can be restored if the on-line portion is corrupted.

STANDARDS FOR THE FUTURE

Many useful standards have been developed for LIS/GIS, considering that widespread adoption of automated land and geographic information systems is relatively recent, and in spite of the very broad range of applications and jurisdictions. Information technology standards from the computing industry in general have been adapted to spatial applications. By focusing on a data orientation (as opposed to a transaction orientation, which is more typical of local government), standards developers have made significant contributions to facile data sharing, a precept of multipurpose land information systems. However, much development remains, particularly in testing and adapting standards to the local level, and in documenting the contents and quality of data bases.

SDTS represents an ambitious effort to develop a single data transfer standard that will work for all types of spatial data. It is not surprising that it seems to work well for many federal agencies, since federal agency staff were the major influence in its development. Whether it works well for local agencies, particularly for land records, remains to be seen; there have been critics of SDTS that suggest it may be inadequate (von Meyer

1991). Testing this standard and developing cadastral and other local application profiles is certainly a challenge for the future. Unfortunately, there is no one stepping forward to meet the challenge at the present time. This certainly would be an appropriate task for Urban and Regional Information Systems Association (URISA), the National Association of County Organizations, the American Public Works Association, and similar professional organizations to tackle.

Beyond the technical side of data sharing, there is a need to develop and publicize good examples of institutional arrangements for data sharing. A "standard" inter-agency model may never exist, but professional organizations can help promote not only what works, but also how and why. The National Center for Geographic Information and Analysis' (NCGIA) "Initiative 9 -Institutions Sharing Spatial Data" may be an appropriate forum (NCGIA-I9 Specialist Report). The development of cooperative agreements, memoranda-of-understanding, data access and distribution policies, and so forth are extremely time consuming. These activities could be greatly facilitated by templates and procedural documents.

Additional work remains on data quality evaluation and reporting. Though SDTS calls for data quality reporting, it has taken a back burner to data classification and data transfer protocols. SDTS calls for the same rudimentary elements of quality developed in the mid-1980s, with little guidance on how to test and document data quality. Little has been published on how to evaluate data quality, with the exception of spatial accuracy. SDTS should be supplemented with working procedures and guidelines. Examples of reporting techniques and forms would be useful, as would examples of procedures for evaluating "fitness for use." There are few good examples of how to take the general information from a data quality report and apply it to a new application. Potential users' criteria may not neatly match the categories of information provided in the quality report.

Users' criteria include:

- relevant: are the data useful in my application?
- specific: is there enough detail/resolution for my application?
- accurate: are the data without error or bias in terms of the requirements for my application?

- precise: were known and repeatable procedures used to obtain and process the data? is the precision of the methods known?
- current: are the data up-to-date (or contemporaneous for historical studies)? if not, is their vintage known?
- complete: are all objects and their attributes included (as appropriate for scale)? are there gaps or overlaps in geographic coverages?
- representative: for data obtained by sampling, were methods statistically valid?
- documented: is lineage information complete, particularly as relates to processing steps, categorization, and modeling assumptions? and
- accessible: are the data available when needed, in a usable form?

It may be useful to have similar information about software. Joe Berry (1993) recently suggested we need "algorithm standards" so users will clearly understand the results and implications of various analyses, particular those where processing options exist such as interpolation and generalization. Benchmarks and guidelines are needed so that users know which computing options are most appropriate for particular applications.

The lack of standards for metadata is a serious impediment to effective data sharing at the present time. The lack of good procedures for documentation and cataloging may also hamper use of spatial information systems within an organization. Fortunately, several groups are working on this issue, including FGDC, NCGIA, and the Association of Research Libraries. Hopefully, their efforts can be coordinated, resulting in a broad consensus that vendors can adapt and incorporate into commercial packages.

Several groups are working on spatial extensions of SQL, the standard query language for data bases. The groups are adding spatial operators such as "within" or "next to" or "connected to" and map-generating functions such as "show me where this combination of conditions exists." This should enhance the ability to remotely query a spatial data base without having to transfer the entire data set or convert its format. As with metadata standards, it would be useful if we ultimately end up with one set of tools, along with the flexibility to adapt and extend it to new needs and situations.

Here is one final note on the "everyone's concern, but no one's obligation" issue of standards. Unlike many professional fields, there is no written or unwritten code of ethics that guides the behavior of land and geographic information system specialists. This is a result of the newness of the field, the diverse backgrounds of participants, and the breadth of applications. However, estimates suggest that over one hundred billion dollars will be invested in automated spatial data systems by the end of the decade in the United States. There will undoubtedly be opportunities to take advantage of the gullible and the naive, and many more dollars spent based on sincere but inappropriate advice. We are all tax-payers and consumers, and so presumably it is in our collective interest to eliminate mistakes and fraud as much as possible. Like any other standards, ethical standards are voluntary. But, early and complete introduction in our education and training systems makes their use easier and more likely.

For reasons mentioned above, ethical standards for LIS/GIS professionals will not be easy to develop. Professions that contribute to the components of LIS/GIS, such as surveying and photogrammetry may serve as partial models, as may some of the application areas which also have codes of ethics, such as planning and assessing. But it will take a broad and concerted effort to achieve consensus. Who will meet this challenge?

SPECIFICATIONS AND PROCUREMENT

It should be obvious by now that implementing an automated MPLIS is not as simple as buying any computer and "GIS" software and plunking it on somebody's desk. Careful selection of these hardware and software needs to be coupled with appropriate system design, automation and implementation strategies, training, application development, and so forth. Many of the details of these components are contained in subsequent chapters. The remainder of this chapter provides an introduction to the process of determining system requirements and the development of a request for proposals (RFP) to purchase hardware and software components of an automated system. The same general RFP process could be used for other components as well, such as data automation services, consulting for system design or implementation, training, and so forth.

SYSTEM REQUIREMENTS ANALYSIS

Though the term "system requirements analysis" may sound complicated, it can be translated simply as determining the appropriate hardware and software needed to meet the demands of users, as identified in user needs assessment (see Chapter 16). A requirements analysis should also include other facets of system operation such as staffing, training, operating environment, quality assurance, cost accounting, system maintenance, system security, and so forth. It is another application of information from a needs assessment and a way to better understand what the final system should "look like." A short-term goal of system requirements analysis may be to develop a request for proposals (RFP) for hardware and/or software. The long-term goals should be to identify technical constraints to successful system operation and to develop appropriate solutions.

Determining software functionality -- its capability and capacity for LIS applications -- is of primary concern in terms of RFP development. The elements of functionality -- for example, data automation, management, analysis, and display functions that LIS software could do -- can be used to determine what will be required in a RFP, given present and future applications. Hardware represents a substantial part of an initial investment in LIS, but the considerations are straightforward and secondary in importance. The gist of the message is to "buy the fastest machine with the most memory that is within your budget." In general, software should be selected first (or simultaneously); the "platform" must support the software that is chosen. Some additional requirements concerning data models, system design, and integration of new technologies into an organization should be considered before making a commitment to a particular hardware and software solution. It is appropriate to develop RFPs after an organization has a strategy for evaluating software and hardware needs and for effectively organizing and using these new tools.

Software Functionality

The functionality of software -- what computer programs are capable of doing and with how much difficulty to the user -- is critical to the success of a LIS. It is also something that is hard to determine through a cursory glance at vendors' publications. Salespeople can always make software appear to be easy (in fact, the buyer must remember that during demonstrations, vendors are generally working with small, error-free data sets on powerful computers).

Before determining specific details of software functionality necessary for certain applications, it is necessary to think about general tradeoffs in customization. Some software arrives with only completely developed application modules -- a tax mapping module, a sewer line module, and so forth. The main advantage is that an organization without much experience can be operational without extensive training or new staff. The main drawback is limited flexibility; if there is an application for which the vendor has not developed a solution, the buyer may be out of luck or may need to pay the vendor to work on particular problems.

At the other end of the customization spectrum is software that is essentially the building blocks for applications. There is a great deal of flexibility in this approach, but someone needs to determine and string together commands for each application. Some vendors with this building block approach offer preprogrammed modules for common applications, and consultants can be hired to help build them as well. A requirements analysis should include some thought about where in this spectrum from highly customized to "building block" software is most appropriate for the personnel of an organization. This includes an assessment of staff experience, knowledge, and educability, and the organization's resources and ability to deal with vendors or consultants when new applications come along.

The first step in selecting software is to determine what functionality is essential and what is desirable for any particular situation. A list of software functionality can provide a basis for noting vendors' software capabilities. Table 20-2 is a checklist of software functionality, derived from several sources.

There are many ways to determine what software functionality is needed for a system, ranging from an informal perusal of Table 20-2, to a formal ranking and composite evaluation. This can be done by technical staff familiar with LIS software, or a consultant who can help decide what functionality is needed for applications. A formal procedure for using the functionality checklist might take the following form:

1. Rank priorities in application development. Determine which applications are immediate needs -- for example, those that must be done for the system to function at all, those likely to provide quick or visible benefits, and those that must be done for political and institutional support. Then, determine what applications are desirable over a longer term and what their relative importance may be.

2. Decide what functionality is essential, what is desirable, what would be "nice to have, but not necessary," and what is probably not needed. For example, if tax parcel mapping and zoning are the highest priorities, then basic mapping software for those functions is essential; if planning applications are anticipated, analytic capabilities such as topological overlay and buffering may be desirable. Assign a relative weight to these functions based on their importance in the overall goals of the system. As a simple example, functions could be given a weight: essential = 5, desirable = 3, nice = 1, and unnecessary = 0.

3. Develop a "request for information" or a formal RFP detailing system functional requirements. Compare the vendors' responses (how they scored their capability) for the functionality you require.

Table 20-2: GIS Software Functionality

<u>User Interfaces</u>
Command-driven user interface
Pull-down or pop-up menu user interface
Icon-based user interface
Batch programs or command files for series of functions
Macro language or shell scripts for creating new commands
Source code or object code library for user program development
Tutorial or other method for self-instruction
An "undo" command to restore conditions prior to command
Recall of previous command(s) for re-execution
Logging of commands or operations
Soft error recovery
  user friendly error messages
  restore data files to original form
  remove scratch files

<u>Data Base Management</u>
Linkage of geographic data with attribute data base management system
Facility for entering data quality information
Facility for recording data lineage
Facility for tracking transactions or updates
Access to attribute data
  direct - by attribute identifier
  direct - by selected geographic feature
  through relational key
  by natural language or SQL instructions
Ability to create, view, and manipulate metadata
Data base operations
  sort tabular or graphic files by attribute or location
  calculate new values by arithmetic or logical expressions
  relate data files by common unique identifiers
  define rules governing behavior of data elements
  create, store, retrieve, and generate standard reports
Provision for organizing files by project
Generation of status reports on content and status of data base
Capability to add data files without regard to size or scale
System security
  password access protection
  electable read only or read/write access for different users
Computer network operation
  access common data file from file server
  data check out / check in procedure

<u>Geographic Data Automation</u>
Manually digitize two-dimensional point, line, or polygon data
"Snap-to" previously digitized features
Photogrammetrically digitized data incorporation
Coordinate geometry: protract lines, angles, and curve; intersect lines (create nodes); bisect angles; locate
  tangents; perform leastsquares traverse adjustment; store curve as radius, arc endpoints, or center

Table 20-2: GIS Software Functionality (continued)

point, arc endpoints; offset parallel lines
Manually encoded raster (cellular) data: raster editing, thresholding, and line thinning; raster to vector conversion; scanned map data - raster; scanned photographic or satellite data
Topological structuring
  manual assembly
  automatic (batch) assembly of polygons from lines
  automated calculations of area, length, perimeter

Data Editing and Error Correction
Attribute data association
  assign (multiple) attributes to geographic features
  associate attributes with completeness check
  attribute range or value checks
  attribute format checks
Select features
  by pointing
  based on attribute value
Insertion or deletion of selected geographic features
"Cut and paste" from update file
Interactive movement of individual points, lines, or areas
Interactive graphic annotation editing
Automated topological error reporting

Terrain and Other 3-D Surface Representation
Contours
Regular gridded Z-values (digital elevation models)
Triangular irregular network (TIN)
Constrain contours by specifying barriers
Calculate cut or fill volume
Determine drainage networks or floodplains
Determine ridgelines or watershed boundaries
Determine viewsheds from user specified points
Compute slope and aspect values
Plot planar geographic features (terrain drape) over 2.5 D net, wireframe, or contours
Plot geographic features in plan or perspective view with shaded relief and hidden line removal

Import/Export
Arc/Info
AutoCad
DEM
DLG
ERDAS
ETAK
GIRAS
GRASS
Intergraph
MOSS
TIGER
Spatial Data Transfer Standard (SDTS)

Table 20-2: GIS Software Functionality (continued)

<u>Data Display and Analysis</u>

Data Retrieval - select and display
- by theme or layer
- within window specified by coordinates or reference map
- within window specified by on-screen digitizing
- by feature names or groups of names
- by logical and Boolean retrievals on attributes

List attribute values of selected features
Report location of feature by pointing
Report straight-line distance or length by pointing
Report along-line-feature (network) distance by pointing

Data Restructuring
- raster to vector conversion
- vector to raster conversion
- map tile or sheet appending
- automatic edgematching
- line thinning or smoothing

Data Transformation
- planar transformations
- "rubber-sheeting" planar transformations
- extract control point coordinates from master file
- incorporation of USGS/NOAA projection package
- incorporation of NOAA-NGS NADCON datum conversion

Overlay
- Graphic superimposition
- Topological overlay
- Sliver removal
- Cross-tabulation
- Area weighted average

Networks
- Maintain line and node attributes
- Determine optimum path through network
- Determine optimum route for distribution through network
- Calculate optimum allocation or collection zones

Other Geoprocessing
- Buffer
- Proximity report
- Nearest neighbor
- Dissolve
- Automated address matching
- Adjacency

Table 20-2: GIS Software Functionality (continued)

<u>Data Display and Information Product Creation</u>
Data Display:
- Generate graphic displays (on screens, plotters, etc.)
- Display vector data with raster (image) backdrop

Information Product Creation:
- Compose products interactively
- Compose products with command files or map templates
- Store, retrieve, and re-display compositions
- User specified scale, orientation, map size, location on sheet
- Display point, line, and polygon data sets
- Display map features: neat lines, grid lines, graticules
- Create and position: scale bar, legends or keys, north arrow, map titles, logos, text
- Interactively position map elements
- Ability to select point symbols, line types, and area fill patterns
- Ability to create, name, store, and select new point symbols, line type, and area fill pattern tables
- Ability to assign by attribute, selection, or lookup table
- Automatically position text at pre-specified point location
- Ability to specify individually for any text string: font, case, size, spacing, color, angle, curvature

Hardware Requirements

Available computer hardware and related peripherals for LIS are generally reliable; if chosen to match the needs of an organization and the requirements of software, they should not be a barrier to successful operation. There are at least five important aspects of computer hardware to consider (these are discussed in considerable detail in subsequent chapters):

- Type of operating system;
- Speed and memory of the CPU (central processing unit; the memory here is referred to as RAM);
- Speed and size of magnetic (hard disk) storage and off-line storage (backup system);
- Network and distributed processing capabilities;
- Compatibility with existing computing environment.

Peripherals such as monitors and input (digitizers, scanners, stereoplotters) and output devices (plotters and printers) also need to be considered. Peripherals selected should be appropriate for applications in terms of speed, resolution, cost, and so forth, compatible with hardware and software, and operable and maintainable by in-house staff.

The continuing increase in storage and processing capacities and simultaneous decrease in costs makes the timing of hardware purchase problematic; it seems that there is always a better machine "just around the corner." This trend is likely to continue for some time though, so the only choice is to accept the fact that hardware, even with upgrades, will be old in five years and obsolete in ten. One approach to this dilemma is to purchase"state-of-the-art" systems (consistent with needs) and allocate funding for upgrades over time. System replacement schedules and long-term maintenance requirements and costs should be included in an evaluation of hardware alternatives.

Again, the functionality of the software should be the main consideration in buying a computer. So as long as the hardware platform supports the software and peripherals, it should be adequate for current needs. Beyond that, maximum affordable flexibility and expandability for future applications and users should be the guide.

REQUESTS FOR PROPOSALS

When the software and hardware requirements for a system have been determined, and at least some of the major system design issues have been addressed, it is possible to develop and release requests for proposals (RFPs). The RFP can include any combination of software, hardware, maintenance, training, data conversion, and design. However, having multiple components in a single RFP may make the document cumbersome and the evaluation of responses complicated.

The basic purpose of a RFP is to solicit proposals for system components that meet design criteria and functional requirements. The functional requirements and proposal evaluation criteria should be clearly specified so that both the organization and the vendors have a clear understanding of what is requested and what is required. Several key elements in a RFP are outlined in Table 20-3.

An example RFP is presented at the end of this chapter, for software and hardware. It contains most of the elements listed above, though not necessarily in the same order. It is a good example of determining functional requirements and translating them into system specifications.

Vendor proposals should be evaluated first on their technical merit, and then on cost. A user may not yet have the technical capacity to understand how shortcuts that allow a low bid may ultimately compromise the system. There is enough competition in the GIS market right now that any anomalously low bid should be carefully investigated. In the related field of photogrammetric services, many vendors refuse to bid on projects required by law to accept low bids. These vendors use a certification to ensure potential customers that their methods are technically valid and to screen out less reputable competitors. No formal certification of GIS vendors currently exists, but reputable vendors will respond to "requests for qualifications".

A. Overview
- nature of the proposing organization
- scope of request for proposal
- scope of project in which purchased goods will be used
- contacts for further information
- responsibility of solicitor and vendor

B. Mechanics of RFP process
- format of response
- proposal due date
- procedure for changes, negotiations, appeals
- provision for multiple proposals from single vendor
- evaluation procedure and basis for contract award

C. Vendor qualifications - who is eligible to respond

D. System specifications - functional requirements and capacities

E. Elements of proposal
- itemized list of deliverables and associated costs
- timetables for delivery, installation, support services, training
- warranties, maintenance, and upgrade procedures
- site preparation and in-house personnel required during installation
- environmental conditions and space required

Table 20-3: Key Elements in a Request for Proposals

SUMMARY

This chapter provided an overview of the standards and procedures that govern the implementation and operation of a multi-purpose land information system. Without appropriate standards and procedures, many of the potential benefits of MPLIS cannot be realized.

Four aspects of standards were discussed - the need for standards, types of standards applicable to LIS/GIS; challenges in the development, implementation and enforcement of standards; and future needs and trends. Standards are needed primarily for data exchange, though many other aspects of system operation also depend on them. Four categories of standards were recognized - application standards, data standards, information technology standards, and professional standards. Data standards, including data transfer, quality, and metadata were discussed in detail. Implementation and enforcement of standards can be a problem, since the standards are essentially voluntary. However, it is easy to recognize that the use of standards has many benefits within and beyond an organization. In the future, there is still work to be done on standards, particularly the adaptation of standards promulgated by federal agencies for use at the local level. LIS/GIS professionals will also be discussing another kind of standard -- professional standards such as certification or licensing.

Two important steps in the MPLIS implementation process were presented. Procedures for determining system requirements and developing requests for proposals (RFP) were discussed because these are critical steps in selecting appropriate components of automated technologies.

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APPENDIX 20-1

XYZ County Land Information System
Request for Proposal for a
Geographic Information System
Initial Workstations and Software

I. Introduction

XYZ County is interested in the development of a multipurpose land information system. Workstations and geographic information system (GIS) software will be purchased for the XYZ County Land Regulation and Records Department (LRRD) and the Division of Systems and Data Processing. XYZ County will select a vendor to act as primary vendor and successfully complete the installation of the system described in this request for proposal (RFP). XYZ County retains the right to bid and obtain additional hardware, software, and/or services separately if it so desires.

Primary Vendor Responsibility

The primary vendor is the vendor who provides a service and receives payment for that service. The County of XYZ will consider the primary vendor to be the sole point of contact with regard to contractual matters, including the performance of services and the payment of any and all charges resulting from contractual obligations.

A proposal may consist of multiple vendors, but the primary vendor must assume responsibility for establishment of services and for coordination of the delivery and installation of the equipment proposed.

II. Proposal Due Date

Six (6) copies of each proposal are to be received by XYZ County up to and including 2:00 p.m., Wednesday, March 15, 199X.

All proposals are to be addressed to:

XYZ County Purchasing Agent
Room 10, County Courthouse
County Seat, WI 54999

The following notation must be in the lower left-hand corner of the transmittal envelope:

Proposal No. 5555
Geographic Information System
2:00 p.m., Wednesday, March 14th.

III. Proposal and Contract Security

No bid/proposal bond or performance bond is required.

IV. Changes in the request for proposal (RFP)

If it becomes necessary to revise any part of this RFP or otherwise provide additional information, an addendum will be issued by the County and furnished to all firms that have received copies of the original RFP. Please acknowledge the receipt of any addendum in the appropriate section, as directed in the addendum.

V. Contract Negotiations

XYZ County reserves the right to negotiate a contract after the successful firm is selected. A copy of XYZ County's Purchase of Services Agreement is attached as Exhibit 1. Selection will be based only on the proposal submitted and subsequent interviews, if any; therefore, the proposals must be complete. Submission of a proposal shall constitute a valid offer, which may be accepted by the county for a period of 120 days following the proposal opening. Term of the contract will be determined at negotiation.

VI. Questions concerning this RFP should be directed to:

Rod Traverse
XYZ Real Property Lister
Room 5, County Courthouse
101 Main St.
County Seat, WI 54999
(608) 123-4567

or

Ada Lottanums
Manager - Data Services Division
Room 25, County Courthouse
101 Main St.
County Seat, WI 54999
(608) 123-5678

Prospective respondents are invited to a pre-proposal meeting to explain the bid procedure and answer questions:

Tuesday, February 13th, 10:00 a.m. - 12:00 noon
Room 5, County Courthouse
101 Main St., County Seat, WI.

VII. Incurring Costs

XYZ County is not liable for any costs incurred in replying to this RFP.

VIII. Acceptance/Rejection

XYZ County reserves the right to accept or reject any or all proposals in part or in total, as deemed to be in the best interest of XYZ County. Firms whose proposals are not accepted will be notified as soon as the selected vendor has been approved.

IX. Taxes

XYZ County is exempt from all federal, state, and local taxes.

X. Scope and Content

A. Scope of RFP

It is the intent of XYZ County to acquire a combination of hardware and software to assist in the creation, maintenance, analysis, and dissemination of land information. This is to be accomplished by automating manual mapping procedures and existing cartographic products, accessing existing and future data bases, and providing computer assisted analysis of the resulting information for the (tax listing, zoning, surveying, property listing, deeds registry,...) functions of the department. It is also intended that the system will be extended to other departments at a future date, and must be capable of sharing land information between county departments and with other interested parties.

The conversion of analog or automated geographic data to the selected software/hardware system is not a component of the RFP; the capability to automate data with various methods is a component (see section XI.D.1).

B. Scope of the Project

XYZ County is currently developing a County-wide Land Information System. It is the county's intent to integrate wherever feasible the land information in all county departments and, where beneficial, to participate in data sharing efforts with federal, state, local, and private entities.

C. Vendor Qualifications

The successful vendor must:

Be continuously and regularly engaged in providing the goods and services described.

Have field support capabilities that enable equipment and software maintenance, repair, or replacement within 24 hours at the County Courthouse in County Seat, Wisconsin

Provide references of at least three clients not associated with the vendor. Include name, address, and telephone number of person to contact.

Provide demonstration of system as proposed, preferably at a customer site.

Provide brief description of experience, education, and professional certifications of individuals involved in responding to this RFP, and individual persons potentially involved in system installation and maintenance.

Provide information required by County's contract compliance officer.

D. System Specifications

1. Functional Requirements

The Proposal should describe to what extent the proposed equipment and software meet each of the following specified functional requirements:

a. Input

Digitizing, including automatic intersection detection and user specified "snap-to" distance

Interactive edgematching

Automated edgematching, based on contiguous geographic objects within user specified tolerance

Automatic topological structuring and error checking

Line thinning/coordinate reduction

Coordinate Geometry (COGO), e.g. metes and bounds etc. Allow creation of a computerized graphics file of parcel boundaries through keyboard entry of survey data. Use angles, distances, curve data, bearings, and azimuths.

Store x, y, and z coordinates in double precision format.

Generate map files from external point/line files from other systems.

Display digital imagery as a backdrop to geographic objects

b. Data Storage and Manipulation

Interactive viewing and modification of geographic objects, text, symbols, attribute tables, and data base records.

Save and recall previous versions of map files by date.

Maintain a history of changes or log of all operations performed on a data set.

Allow interactive entry, editing, and output.

Facility for entering data quality information.

Graphic data base that interacts with relational attribute data base.

One or more programmable command languages that enable county staff to develop menu or icon driven applications.

Access coordinate data in product's standard form. Allows integration of specialized routines such as a custom transformation.

Break apart or put together geographic objects, and to merge or dissolve them via an unlimited number of attributes.

Maintain line and node attributes, including direction, conductivity, and barriers.

Retrieve and manipulate individual or classes (themes, layers) of geographic objects, each of which is linked to a relational data base.

Create a "seamless map" of entire county, dividable into submaps based on user defined partitions.

Allow one user update, many user reading of submaps.

Gazetteering function, providing user access to a seamless base map by graphically or textually identifying a point.

Ability to download/upload data to personal computers and XYZ County's [name brand] mainframe computer.

Ability to create and read data in public standard interchange formats such as ASCII, DLG III, IGES, DEM, TIGER.

Ability to create and read data in proprietary standard interchange formats such as AutoCad DXF, Intergraph SIF, ARC EXPORT, ETAK.

Ability to load attribute data from (mainframe data base management system software) and Dbase III-IV.

Ability to convert map file coordinates between standard map projections such as State Plane Coordinates and UTM, and latitude/longitude and/or incorporation of USGS Standard Cartographic Transformations software.

Ability to convert map file coordinates between NAD 27 and NAD 83 and/or incorporation of NGS NADCON software.

Ability to do planar map file coordinates transformations using least squares adjusted affine method (e.g., transform digitizer inch space into map projection coordinate system).

Network with other workstations and computer systems including DOS microcomputers, IBM 43xx, DEC VAX, NCR 9800, Wang VS

Ability to handle power outage with minimal loss of data (unsaved data only)

Prompt for saving data when logging off.

Diagnostics to indicate nature of errors.

On line help for commands.

On line command usage prompt, or allowable command prompt.

Access to data for update and/or viewing can be protected by password at file level. Prefer capability at record and field levels.

Control of access by user to read only, read/write, or no access to individual files. Prefer capability at record and field levels.

Control of access by feature or program module.

Current capability or future directions in software development should include distributed processing and distributed data base management. In the near future, XYZ County will need to be able to access data bases from several locations at one workstation without copying entire map files to that workstation.

c. Analysis

Compare single and multiple overlays of point, line, and polygon data and their associated logical data bases. Produce an updated map file and set of logical data bases showing the results of the overlay.

Derive unions and intersections of polygon sets. Compare polygon sets to points or segment features and provide reports of geographical association.

Topological Overlay including: polygons on polygons, lines on polygons, points on polygons, points on lines.

Detect adjacency of polygons.

Detect connectivity of lines.

Create "buffer zones" of specified distance around lines, points and polygons; identify other geographic features found within buffer zones.

Calculate lengths, areas, perimeters, number of occurrences of geographic objects.

Dissolve or merge a map file on one or more attributes

Reclassify attributes based on mathematical or logical expressions, or feature locations.

Polygon centroid calculation

Proximity analysis: find nearest neighbor of an entity, find all entities that fall within a specific distance of an entity.

d. Output

Ability to create, store, and retrieve: graphic figures, symbols, legends, and text.

Position graphic elements automatically or interactively.

Associative dimensioning of text.

Full control of scaling and format.

Use map templates or command files to generate map series.

Output digital image data as a backdrop to plots or screen displays.

2. Hardware

The proposal should describe the capabilities and cost of each piece of hardware proposed and to what extent they meet the following requirements. The proposal should identify optional equipment and pricing such as a faster CPU or more disk space. The proposal should identify any hardware limitations that would prevent future expansion of the system to accommodate new users, applications, or data bases.

Workstation/CPU

Multi-user CPU or capable of being networked to other CPUs/workstations. Prefer hardware that supports multi-tasking capability.

Support for microcomputers as terminals or as distributed processing workstations.

Operate in normal office environments.

Have adequate disk storage for purpose intended.

Printer

Capable of producing all reports generated by proposed software. Prefer 132 column capability, ability to produce draft versions of graphic output. Prefer laser printer

Tape Backup system

Adequate for easy backup of all disk storage with minimum number of tapes. Prefer ability to run unattended.

Plotter

Multi color/pen capable of producing 'E' size drawings.

Digitizing Table/Board

'E' size active area.

Precision $\leq$ .001; accuracy $\leq$ .003

Workstation/Monitor

19" High Resolution Color Graphics Monitor adequate for expressed purpose.

Keyboard

Full size keyboard

3. Software

Describe to what extent the proposed system includes each of the following and the associated cost:

a. Geographic Information System Software

It is expected that one or more modules of software will be proposed to meet the functional requirements listed in section D-1. Describe any additional capabilities of the software proposed beyond what has been specified in D-1.

b. Operating System

Capable of supporting all hardware and software functions listed in Proposal

Supports multiple users.

Supports multi-tasking.

c. Applications Software

These are functional modules of software that may be contained in the software proposed or be available as a separate option. If available as a separate option, a high degree of integration with the proposed software is expected.

(1.) Support for field data collector

Accept raw survey data from common field data collectors. Have ability to load field data collectors with survey layout data.

(2.) Network Analysis

Provide capability for analyzing linear networks such as street networks, streams, etc.

Capability to select optimal path

Flow Simulation - linking volume, speed, and direction to line elements.

Time/Distance districting - specify a range of values for travel time or distance from a selected point and compute polygon boundaries, enclosing areas that meet criteria.

Connectivity analysis

(3.) Facilities Management

Link map symbols to information in inventory data bases for display, quantification, and reporting.

(4.) Digital Terrain Modeling

Provide for three-dimensional surface and contouring analysis of topographic information.

Generate topographic contours from user defined elevation points.

Create profiles for cut and fill calculations.

Produce earthwork quantities listings.

Transfer of data files to data collector for field staking.

(5.) Road Design

Create, combine, and test different versions of highway design.

(6.) Raster to vector conversion

Ability to convert raster data into vector data usable in proposed product.

d. Utilities

Capable of exporting data to and importing data from all major GIS software. List products/formats supported.

4. Training

a. Describe proposed training.

Specify length of time, number of people in attendance, types of training, topics covered, location, and cost.

b. Identify optional training and costs.

5. Support

Describe support included in proposal and associated cost.

6. Documentation

Describe the documentation provided with proposed hardware and software and the number of copies provided.

7. Equipment Availability

Equipment proposed in response to this RFP must be commercially available as of the date of the vendor's reply to this request. Software must meet the technical requirements of this RFP in a current release.

XI. Proposal Format

Each proposal will consist of information that will be useful in assisting the XYZ County evaluation team in analyzing your proposal and will include:

A. The green signature page, signed, on top. You only need to return the original signed page

B. Vendor Information Response

Furnish a company history and any additional information that will substantiate vendor company's stability, qualifications, and experience with Geographic Information Systems.

Provide a minimum of three references of customers with similar systems to the one proposed (include company name, address, telephone number, and contact person).

Provide brief description of experience, education, and professional certifications of persons involved in responding to this RFP, and persons potentially involved in system installation and maintenance.

Indicate the total number of installed systems of the type proposed.

C. Timetable for Delivery, Installation, and Training

Provide a timetable for delivery, installation, and user training for proposed system. Identify tasks of both vendor and user. Identify any special preparation required by user.

D. Description of the equipment, software, and services to be provided, with costs

Describe the extent to which the items proposed meet the system specifications outlined in this request for proposals.

To the extent possible, indicate the costs of each item proposed separately in the following format:

Software

For each separately priced module:

Initial cost

Annual maintenance

Hardware

For each separately priced component:

Initial cost

Warranty period

Optional warranty term and cost

Training

Amount included with purchase of hardware and software

Optional training costs

Total Cost of Hardware, Software, and Training Proposed.

Total first year cost

Total annual costs after the first year

E. Multiple Proposals

Vendors who wish to submit multiple proposals are invited to do so. If more than one proposal is submitted, all must be complete and comply with all instructions in this RFP. Each proposal should be clearly marked Proposal #1, Proposal #2, etc., on the cover page.

XII. Proposal Evaluation Criteria

Proposals will be screened to ensure that they meet minimum requirements for proposal format, vendor stability, references provided, etc. A review of the qualifying proposals will identify potential vendors that most closely meet the needs of XYZ County. Functional capabilities, operating times, and overall cost will be among the criteria considered in evaluating proposals.

After review of the proposals, two or more potential vendors will be selected and asked to demonstrate the capabilities of their proposed systems by performing a series of tests designed to show if and how a system meets selected criteria.

Basis of Award

The award resulting from this RFP will be made to the vendor that submits the response that, in the County's opinion, best serves the overall interests of the County. Some of the factors that will be considered in the evaluation include (not necessarily in order of importance):

Cost of hardware, software, maintenance, and training.

Cost of operation.

Proven ability of vendor to provide similar systems within established guidelines.

Evaluation of responses to the RFP and the references provided from other clients.

Ability to meet the system specifications as stated in this RFP.

21 INTRODUCTION AND OVERVIEW OF MULTIPURPOSE LAND INFORMATION SYSTEM AUTOMATION

Michael J. Kevany

INTRODUCTION

The various components of an MPLIS are described and methods for their modernization are defined in prior sections of the Guidebook. The concepts, issues, and solutions to the MPLIS were described in those sections. One of the prominent mechanisms for modernization of land information management is automation. Automation is the use of computers and information systems to manage and process land-related information. This section describes the automation of an MPLIS. It should be noted that automation is not essential to an MPLIS, though it offers many opportunities for efficiency and benefits. While an MPLIS can be operated in a paper/manual environment, some aspects of the MPLIS presented in earlier sections will be difficult or impossible to achieve without automation. For example, multi-layer analysis using the functionalities discussed in Chapter 11 are not possible without automation.

This Guidebook does not attempt to describe all aspects of computers or information sciences. Readers that require basic knowledge of computers are encouraged to seek that knowledge from other sources directed to that topic. This Guidebook will provide some basic information on computers and information systems, but quickly moves to the employment of that technology in an MPLIS. It is intended to provide information on what automation of an MPLIS is and how to achieve automation. An automated MPLIS can be extremely complex, requiring technical skills such as systems analysis, programming, and data base administration, as well as knowledge of land records and the processing of land information. The actual automation of an MPLIS, even in jurisdictions, will require these technical skills. In many cases it may be necessary to develop internal skills through extensive training or to acquire the skills from outside sources including government technical assistance programs, other jurisdictions, and the private sector.

Michael J. Kevany is Vice President, PlanGraphics, Silver Spring, Maryland.

GUIDEBOOK AUTOMATION SCOPE

MPLIS automation is discussed in Chapters 21-24. This chapter provides an overview to MPLIS automation technology concepts, introduces key issues in MPLIS automation, identifies the main automation areas in MPLIS, and provides some of the terminology used in MPLIS automation. Chapter 22 examines automation issues including hardware, software, data, organization structures, staffing, and other components of an automated MPLIS. Chapter 23 provides guidance on development, acquisition, and implementation of an automated MPLIS. Finally, Chapter 24 describes a model automated MPLIS, including the various functions and components of the system.

AUTOMATION OF AN MPLIS

Automation is one approach available to implement an MPLIS. Automation may take many forms and can range from a simple PC with word processing or spreadsheet software to a large mainframe computer with a complex, integrated set of many applications. The appropriate form depends on the requirements for the MPLIS, the existing land records, the volume of land record transactions, the extent of automation to be performed (single function to complete, integrated system), and the organizational responsibilities and structure of the implementing agencies.

The current information technology environment may be one in which many departments share a central computer system, which is typical of many local governments. This system supports a large number of terminals throughout the organization. Individual applications or processing systems may have been developed for various land records functions such as register indexes, permits, and tax assessment. In many cases these applications, programs, and systems were developed many years ago using what are now dated concepts and technology. An opportunity may now be available to modify land information processing while updating to new technology as an approach to MPLIS modernization. Another similar model, though at a smaller scale, is also found where central processing is performed with one or more minicomputer(s) that operate through numerous terminals throughout the organization.

In some organizations, especially small jurisdictions or organizations with a decentralized computer environment, microcomputers are used for information processing. A great proliferation of PC use has occurred due to the low cost and ease of use of these devices. They generally use a prepackaged word processor, data base manager, and/or spreadsheet to perform functions and manage data. These PCs frequently operate in a stand alone individual mode, though in some cases these are also linked as terminals to the host computer.

An important concept in these alternative environments is the location of software (on a host or local PC) and of data storage and management. Recent trends include distributed processing where software and data operate locally on a PC or workstation with a network to link multiple devices for sharing data and resources. This approach will be described in more detail later in this chapter.

Important tradeoffs between centralized and decentralized approaches must be evaluated. For example, mainframe means easier integration and implementation of standards, but at the same time, use and interest in a system may be suppressed. PCs mean easier development of applications, but more difficulty in integration of the entire system. Distributed systems have some advantages of both PCs and mainframes.

In a very few jurisdictions today, there is little or no existing land information automation. In these cases, it will be necessary to develop an entirely new system affording opportunities for flexibility with no preexisting constraints, but also requiring new resources and skills not currently possessed by the organization.

The environment for the management and processing of information regardless of its current form will be very important to automation of an MPLIS. It may require that the MPLIS be implemented on existing systems or may offer opportunities for the acquisition of new systems.

WHY AUTOMATE AN MPLIS?

Many benefits are available to an MPLIS through automation. These include:

- Increased speed of processing information
- Productivity improvements for persons conducting MPLIS activities
- Flexibility in retrieving and reporting information
- Minimization or elimination of redundancy through the sharing of data and equipment
- Rapid response to citizen inquiry or processing
- Minimization of some types of error in the delivery of information
- Integration of multiple sets of data to support decisions
- Improvements in the quality and timeliness of decision making
- Expansion in the type and extent of analyses that can be performed
- Improvements in availability of information to staff, management, and citizens.

These benefits can be obtained from automation of an MPLIS in virtually any organization. The specific opportunities will depend on the local conditions of the individual organization that implements such a system. Some examples of specific benefits include rapid response to parcel inquiries by county officials or members of the public; more effective assignment of personnel; integration of parcel data from assessments, permits, and planning functions; elimination of multiple map updating or data entry tasks; improved editing and verification of data accuracy; consideration of multiple aspects of a decision; improved scheduling and allocation of resources; and easy access to active and archived data.

In many cases, it will be necessary to identify the benefits to justify the investment in MPLIS automation. The benefits may be quantifiable or non-quantifiable. Chapter 23 addresses the feasibility study as a task in MPLIS automation. Also see Chapter 16 - "Needs Assessment." Examples of mechanisms for identifying and evaluating benefits from automation are presented in that chapter.

One of the most important aspects of automation of an MPLIS is the greatly increased potential for sharing of information across the multiple functions of land information through an automated system.

AUTOMATION INVESTMENTS

To achieve automation benefits requires an investment in hardware and software, data base development, staffing and training, and development of new procedures. This investment may be a few thousand dollars in a small jurisdiction or for a single function, to several million dollars in a major jurisdiction, particularly when a large graphic component and its associated, extensive data base is to be implemented.

The relationship of the terms MPLIS and GIS are the subject of some differences of opinion. As defined by McLaughlin and others, a GIS incorporates all geographically referenced information and thus is global in scale. An LIS in this taxonomy deals with a more limited subset of information specifically related to land ownership parcels.

For purposes of this chapter of the Guidebook, however, a GIS is defined much more narrowly. Here we narrowly define GIS as the hardware, software, communications, and data base of a specific type of automated system that is capable of managing map data, relating attribute data to map features, and performing spatial analysis functions. This definition distinguishes a GIS from systems that merely manipulate spatial data and spatial data layers, but have no analytical capability (e.g., many early and some current CAD systems).

This definition of GIS makes it a specific component of the MPLIS that is the focus of this Guidebook. GIS technology has become extremely popular in many local and state governments across the United States. Data in a GIS may be of various scales, but will require conversion of existing maps to computer-readable form. The development of data bases that facilitate the use of an MPLIS with full capabilities to manipulate and analyze spatial data (i.e., a GIS as used here), is generally a costly aspect of an MPLIS.

An investment in time will also be required. It may take months or years to define requirements, design systems, acquire systems, develop data bases (e.g., load and establish automated spatial data holdings), implement systems, and train staff before an automated MPLIS is fully operational.

The funds allocated to MPLIS automation should be viewed as an investment in an infrastructure and corporate asset that will return value to the organization. These investments of funds, resources, and time should result in improvements that pay back and extend the value of the investment or else the automation should not be undertaken. The scope and extent of the automation should be balanced against the investment required and the benefits gained. The level of investment should be limited to the most cost-effective level and extent of implementation. A more detailed discussion of techniques for use in economic evaluation of automated MPLIS systems can be found in Chapter 15.

AREAS OF AUTOMATION

This section of the Guidebook addresses the automation of functions, data, maps, and products described in the previous sections of this Guidebook.

Some of the basic functions within a local government that will make use of an MPLIS include:

The Registry, where deeds and other ownership instruments are recorded;

Tax assessment, where information for determining land and improvement value is used and where tax responsibilities are recorded;

Various permitting and zoning functions, where land conditions, locations, and development permissions are recorded and used;

Land use planning, where information about land use and development is integrated and analyzed; and

Public works and transportation, where facilities and utilities information is recorded and managed.

In addition to these primary MPLIS functions, a number of other functions in local government acquire and use land information. These include inspections by the fire and health departments, police incident reporting, emergency planning, business licensing, parks and recreation, environmental protection/conservation, and well and septic tank permitting in health departments. A very important recently added function, the responsibility for reporting information on hazardous materials, may well become a major function in many jurisdictions.

Each of these functions will contribute data to the MPLIS and will draw on data provided by other functions when a broad scope MPLIS is implemented.

The concepts for these functions are basically the same in automated systems as were described in earlier chapters. Concepts such as unique parcel identifiers, sharing of common land records, large-scale mapping, and others can often be implemented more effectively in an automated system, than can be done manually. Automation may be applied to parts or all of these functions and ideally to an integrated combination of many or all functions.

THE AUTOMATION PROCESS

Automation of an MPLIS involves several steps. Whether automation is for a simple PC application in a small town or a multiyear, multimillion dollar project in a large county, the same basic steps should be conducted. The difference will be in scope, level of effort, and time . An individual step in a PC project may be an hour or two of one person's time, while in a major project it may take six months, cost tens of thousands of dollars, involve numerous staff and managers, and include the services of a consultant or contractor.

The automation process, to be described more completely in Chapter 23, can be divided into several steps, including:

- Perform Feasibility Study
- Perform Requirements Analysis
- Prepare Strategic and Implementation Plan
- Establish Organization and Train Staff
- Design Automated System
- Design Automated Data Base
- Acquire Hardware, Software, and Related Technology
- Install and Implement System
- Develop Initial Data Base
- Design and Develop Application Programs and Operating Procedures
- Conduct Pilot Project
- Establish System Management Procedures
- Establish Data Base Administration Procedures
- Complete System Acquisition
- Conduct Automated Production Operations.

These steps must be adapted to the specific environment. Some steps may be minimized or bypassed if they are unnecessary in a jurisdiction. The steps may be carried out in a different order than indicated here. Prior to automation of an MPLIS, a general plan for the project should be prepared and, as noted above, an implementation plan should be prepared as a part of the project.

KEY ISSUES

Many issues must be addressed in MPLIS automation. Some issues establish the scope and level of resources, others involve policy and management alternatives, while still others involve the technology to be employed. Issues that should be addressed are discussed here.

TERMINOLOGY

The computer and information systems field is rife with specialized terminology. There are many initials and acronyms used, and common English words can mean something different in the information-systems world than in common usage. It is important for the person who is anticipating automation of land records to at least become familiar with the key terms used in the field. A short list of acronyms and key words is included in Appendix 21-1.

There are many more terms that may be useful that can be found in the Guidebook glossary and in other information systems and land related professional documents.

PC vs HOST PROCESSING APPROACH

An important design question is whether to implement the MPLIS software and/or data base on one or a network of PCs, workstations, servers, or use a host processor (minicomputer or mainframe). A variation on this issue arises with a GIS where the common configuration involves a network of graphic workstations and client-server or mainframe processor.

The capacity and processing requirements and extent of automation, as well as current information systems policies, will impact this decision. There are clear advantages and disadvantages between alternatives that must be evaluated. Comparison of these approaches is discussed in more detail in Chapter 23.

SPECIAL DEVELOPMENT vs OFF-THE-SHELF PACKAGES

An important system development issue is whether to develop MPLIS programs specifically for the organization and functions or to acquire off-the-shelf packages for part or all of the MPLIS. Extension of the issue involves use of a package as delivered by the system vendor or modification and tailoring to the unique environment. Again, a GIS provides a special case where most prepackaged GISs take the "tool box" approach, requiring extensive application development following acquisition of the package. Further discussion of these alternatives can be found in Chapter 23.

DATA BASE MANAGEMENT SYSTEM vs PROGRAMMING LANGUAGE

The MPLIS may be implemented through use of modern Relational Data Base Management Systems (RDBMS) or a standard programming language such as Basic or COBOL may be used. While this issue is closely related to the prior one, it is in fact different. These are software packages that are purchased "off-the-shelf," but used to develop special applications. The RDBMS may be used as a part of an off-the-shelf package or may itself be used to develop a unique system in an individual organization. The RDBMS and query language offer powerful tools for implementation of a shared data MPLIS. They do, however, have computer resource overhead that may be avoided with custom programming.

INDIVIDUAL APPLICATIONS vs INTEGRATED SYSTEM

An MPLIS involves several individual functions or applications as noted above. The automation of an MPLIS may take place through the automation of one or more individual applications. These applications may be self contained and manage their own data sets. An alternative is a comprehensive integrated MPLIS in which multiple or all applications are developed as an integrated system sharing resources and data base. A variation on this dichotomy is a design for an integrated system that is implemented in phases through automation of individual applications in accordance with an integrated design and implementation plan.

GRAPHIC vs NONGRAPHIC DATA

An overall MPLIS may be capable of processing nongraphic alphanumeric data only or may handle both graphic map features and nongraphic data through GIS capabilities. The addition of graphic functions adds significantly to the capabilities and value of an MPLIS, but also adds to the costs and complexity of system development. The integration of graphic and nongraphic data allows new forms of retrieval, analysis, and display, including sophisticated geographic or spatial analysis.

USE OF NEW TECHNOLOGY

Many components of new technology useful to the MPLIS have become available recently and will likely proliferate in the future. Included are the RDBMS mentioned above, graphic workstations for handling map data, raster data processing, imaging systems for document recording, 4GL for user ease, "windows" for simple access and operation, CASE (computer aided software engineering) tools for applications development, and user interface techniques. These offer many new capabilities for enhancement of the MPLIS. With the rapid evolution of relevant technology, the developing organization faces the choice between long standing "tried and true" and the new "leading edge" technology.

INDUSTRY STANDARDS

Many industry standards have been developed or emerged that facilitate integration of systems and sharing of resources. These include some of the items noted above such as the DOS and UNIX operating systems, SQL as a query language, X Windows for accessing applications, standards for communications, including OSF/MOTIF, and standards for data sharing.

CONCEPTS UNDERLYING AUTOMATION

Because automation of an MPLIS can take so many forms and may vary dramatically in scope, it is difficult to present a concise description of an automated MPLIS. This Guidebook presents a basic concept for an overall comprehensive MPLIS and suggests variations that may be developed in the interest of providing a guide to automation. Each organization, however, must design and develop a system that best suits its requirements, resources, and environment. The automation of an MPLIS is presented here as a combination of modules and components so the reader may redefine the basic building units to form an automated MPLIS that satisfies the local requirements within the constraints and opportunities of the local environment. The components identified here include hardware devices, software, data sets, and procedures. The modules identified include a cross section of specific MPLIS applications found in a local government. Functional modules are composed of hardware, software, data, procedures, and staff. The relationship of these components and functional models is depicted in Figure 21-1.

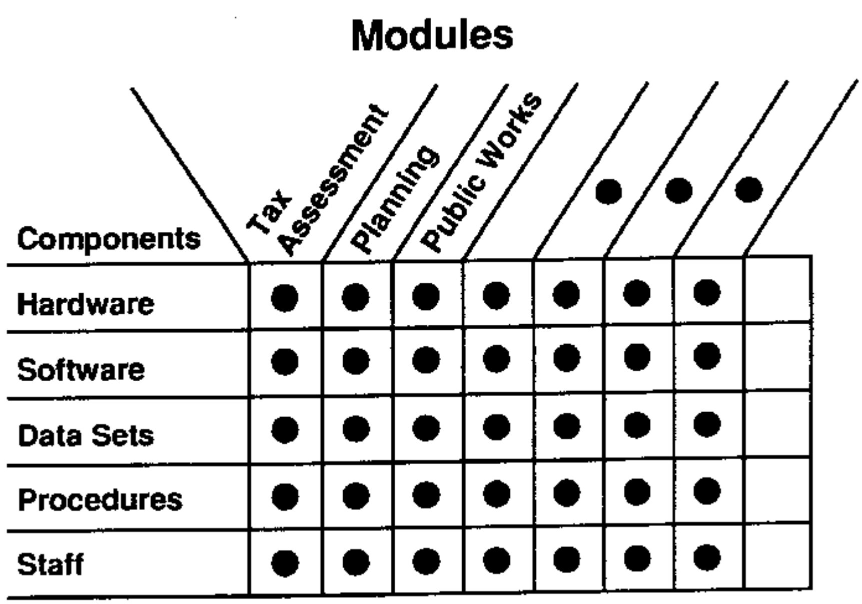

Figure 21-1: Components Support Functional Modules

The automation of an MPLIS is based on several important concepts that direct its design and provide its benefits. Automation of an activity opens many avenues for improvement in productivity, providing additional access to information and supporting new activities that were not available in a paper/manual mode of operation. The basic concepts underlying an MPLIS design include sharing of data through common data sets and/or access mechanisms, standards to ensure the compatibility and integratability of records, flexible access to data, electronic storage and exchange of data, and tools for data management, retrieval, and analysis.

SHARING

Much of the MPLIS automation concept focuses on the sharing of data. This may be the most important dimension added through automation. This concept means that when data are captured and stored for one function or organizational unit, they become available to others. This supports a minimization or elimination of redundant data acquisition and storage and minimizes errors or inconsistencies that arise from multiple organizations maintaining separate sets of data on the same objects. The sharing concept involves several aspects:

1. Data must be stored in a manner that supports access from multiple organizations, functions, and locations. Modern automated technology provides various mechanisms for achieving this from management of central data files with direct access, through terminals in the individual organizations, to networks of distributed data locations with sophisticated data management tools to maintain data and provide access to users throughout the network.

2. Individual users must be able to enter, retrieve, and process data available in the shared sets conveniently within their offices and as part of their normal operations.

3. Data must be defined in a standard manner and standards for quality control must be established and adhered to so that each organization using the data understands what is available and the use that can be made of them.

4. The integrity of the shared data must be maintained through computer technology and procedures that guard against erroneous or accidental entry or modification of data and that ensure that all data in the data base conform to established standards.

Sharing is depicted in Figure 21-2. As an example, a basic parcel record may be maintained with essential parcel characteristics. This may be accessed from various functions to view basic data, verify data elements such as an address being entered in a function, or extract data to be stored with the function-specific data set.

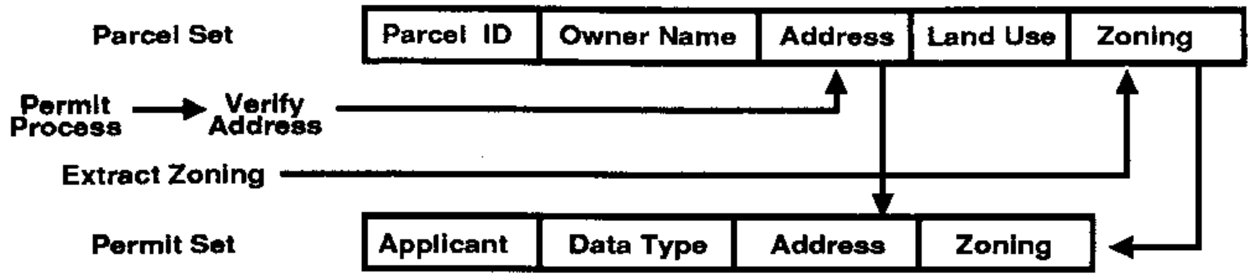

Figure 21-2: Data Sharing - Data Verification and Extraction Process

There are many functions included in an MPLIS, most of which can share some data with other functions. Some functions specifically store and manage data about the land. Others use land information to support administrative, regulatory, tax, planning, and other activities. One of the key concepts to support sharing across these several functions is the definition of land or geographic units for which the data will be recorded. The most common unit for an MPLIS, one which is almost universally used across local government functions, is the tax (assessment) parcel. This unit may be defined in several ways and a standard definition is required for the MPLIS within a jurisdiction. It is typically a contiguous area within a single ownership that is the basis for property taxation. The definition of the parcel will allow it to serve as the common geographic unit for the design of the MPLIS. A substantial amount of land-related data can thus be defined in terms of parcels and processing operations can use the parcel as the primary unit. (The other major type of land data concerns resources, with most resource data defined by resource boundaries into polygons.) Data can also be stored within this concept as aggregations of parcels, e.g., blocks or census tracts, or as subunits of parcels, e.g., buildings or units. (See Chapter 13 for further discussion of the parcel map.)

FLEXIBLE ACCESS TO DATA

To support efficient operations and sharing of data, the automated concept includes mechanisms for flexible access to data. Flexibility encompasses three aspects:

1. There must be flexibility in the physical location from which access can be gained, i.e., each organizational unit must be able to gain access from a convenient location within its offices.

2. The flexibility must allow each user to access the data in a form or through retrieval criteria that is

compatible with its normal operations. That is, it must be able to retrieve on a specific key, such as address, name, or case number, that is used in its operations.

3. The automated MPLIS must retrieve and display data in a format and media convenient to each organization. This may mean multiple formats to suit multiple organizations.

ELECTRONIC STORAGE

The MPLIS automation concept presumes the data are stored electronically in the automated system to allow the various automated functions to be performed. There are numerous alternative forms and formats for electronic data storage. The most effective alternative will be based on the requirements, environment, and resources of the organization. The primary requirement, however, is that data be converted to electronic form and indexed and organized in a way that facilitates rapid retrieval and easy use.

TOOLS

The automation concept also includes a suite of tools to be used to enter, store, retrieve, analyze, display, and report data. These tools include hardware devices for automating (digitizing), accessing, storing, and displaying data, as well as software to manage and process data. The tools are integrated to create an efficiently operating system supporting the numerous MPLIS functions.

AUTOMATION COMPONENTS

An automated MPLIS is composed of several components that are interrelated in an overall configuration. The components include:

Hardware devices that support the various entry, storage, processing, and display functions;

Software that control the performance of functions and manage the data; and

Communications devices that interconnect the devices of the configuration.

The individual hardware components are listed in Table 21-1 and described in more detail in Chapter 23 of the Guidebook. In addition to these system components is the MPLIS data base component. The data base component is an additional major part of the MPLIS. The many data classes that make up the data base are described in Chapter 23. The following is a discussion of general hardware, software, and data components.

TABLE 21-1
HARDWARE COMPONENTS

Processors
Workstations
Servers
Tape Units
Disk Storage
Terminals
Printers
Digitizers
Graphic Display Monitors
Plotters

HARDWARE CONFIGURATION CONCEPTS

Three basic hardware configuration concepts are found in an MPLIS. The most common currently installed configuration in many local governments is a central processor-based system. In this approach all processing and data management are performed on a central host processor that may be a large mainframe computer or a minicomputer. Terminals are either linked directly or through modem and telecommunications to the host processor to provide access to the various users. This approach may include only a few terminals or hundreds of terminals tied to a large mainframe.

The second option is a network of interconnected processors. This distributed approach may include mainframe and minicomputers and PCs or workstations with internal processors. Users may operate the system through terminals as in the central approach or through local DOS or UNIX-based processors. In the latter case, the software is resident and processing may take place locally on the user's device. In this case, the data may be stored and managed in various configurations, such as on a central processor-managed mass storage device, on a server device specifically dedicated to data management, on multiple devices throughout the network, or on storage devices of the PCs or micros. If data are distributed throughout the network, there is a requirement for data management software to control access and integrity and for procedures for entering and maintaining data. Such procedures or software are necessary under any configuration in order to ensure integrity and access to the data base. (A detailed discussion of alternative concepts and approaches to processing and data bases is contained in Chapter 22.)

The third alternative is a PC-based system. In this approach the MPLIS is operated on one or more PCs. In its simplest form, a PC is used for managing land data for a small jurisdiction or a single module in a larger jurisdiction. The PC would host software and data and perform all processing. Recently, PCs are being interconnected through a network to share data, operating similarly to a workstation network.

For any alternative, the configuration must also include disk and mass storage devices with adequate capacity for the MPLIS software and data base, terminals for interaction, peripheral devices for printing reports, and tape or disk devices for backup and transfer of data to other systems. If the MPLIS includes full spatial data manipulation and analysis capability (i.e., GIS capability as used in this chapter), the system must also include graphic data entry (digitizer and scanner) and output (plotter and graphic display monitor) devices. These devices are described in more detail in Chapter 23.

SOFTWARE COMPONENTS

The MPLIS will draw on several software components as shown in Table 21-2. The components can be thought of as an integrated structure in which each component fulfills specific roles in providing capabilities to the MPLIS user. Figure 21-3 is a diagram that indicates a logical software structure.

TABLE 21-2
SOFTWARE COMPONENTS

Operating System
Data Base Management System
Graphics Data Management
Programming Languages
Application Development Tools
Application Programs
Commercial Program Packages
4GL
Communications Software

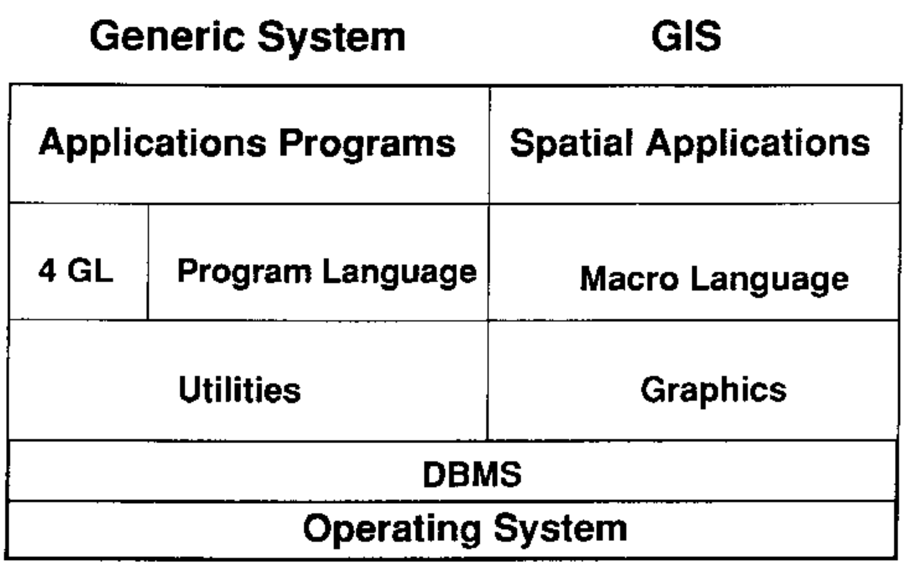

Figure 21-3: Logical Automated MPLIS Software Structure

The structure is built on the operating system that provides basic control, resource management, and processing functions. The operating system may conform to an industry standard such as UNIX, it may be vendor specific, or it may be a standard that has become the industry standard (such as DOS for 286, 386, and 486 processors). On the next level above the operating system are components used to develop the specific capabilities of the MPLIS. These components vary depending on the sophistication of the

MPLIS. In a simple form, this may be merely a programming language, such as COBOL or BASIC, and utilities that perform standard copying, sorting, merging, and other operations. In this case the user's application programs are developed in the programming language, drawing on utilities as appropriate. Pre-programmed commercial packages for particular applications may also use this approach (e.g., tax-listing or CAMA (computer assisted mass appraisal)). This has been the most common approach for MPLIS development in jurisdictions that started automating a decade or more ago. While very simple structurally, it can provide very complex processing capabilities and extensive service to a large number of users.

Another simple approach involves a commercial package data base management system (DBMS), spreadsheet, or word processor. This approach is very common with the use of a PC. In this case, user services are provided directly by the standard package, using general purpose screen and report generation operations, though it may still require programming for particular applications. The approach may use one or a combination of these packages.

The full complement of software components currently available to an MPLIS includes a DBMS for management of data in a standard structure that can serve multiple applications and will facilitate the sharing of data across applications. The utilities components may also be incorporated in application development. More recent components now available include SQL, 4GL, and macro languages that allow users to develop applications more easily. These tools are used to develop forms, menus, reports, and displays to interact with systems and retrieve and organize data to generate displays or reports of required information. Computer assisted systems engineering (CASE) technology is also used to facilitate the design and development of data bases, programs, and systems. Some of these components are relatively easy to use, not requiring extensive computer programming experience. (See Chapter 22 for further discussion of CASE technology).

On the top level of the structure are the application programs, developed using the tools of the other components. The application programs provide the services of the MPLIS directly to the users performing the various processes and producing the displays or products required by the system users. The application programs may be custom developed for the organization or purchased from a vendor.

Figure 21-3 also helps explain the relationship between the overall MPLIS system and the GIS as defined in this chapter. Where a GIS is implemented as part of the MPLIS, it will use the same or similar components as those described for the MPLIS; but, in addition, it will have graphics, spatial analysis, and its own macro components. The graphics component will perform the specialized processing of the map/graphic images. The spatial analysis components will perform specialized functions such as polygon overlay and network analysis. The macros will specifically provide GIS functions for application development.

As noted elsewhere, the software may be employed in various strategies. The user's applications may be developed specifically for an individual organization and function. Alternately, standard, off-the-shelf software may be acquired to perform one or more functions. So, for example, there are standard registrar, permit management, and other MPLIS packages available. The application may also be developed through programs written in the programming language or may be developed using the tools of the DBMS, 4GL, or macros. Each approach has advantages and disadvantages and the approach taken should be based on a careful analysis of the requirements, resources, skills, and operating environment of the organization. The various components are all described in greater detail in the next chapter of this Guidebook.

DATA BASE CONTENTS

A comprehensive multiuser MPLIS will contain a wide range of data. The data can be divided into three classes for purposes of understanding the MPLIS:

1. Identification of locations or records
2. Basic characteristics of a feature (location or record)
3. Individual module-specific data

The first class is data that provide *identification of locations or records*. These identifiers are used to retrieve data and to relate data of a common type or for a specific geographic location. One or more identifiers must be included with each data record. The most important identifier in the MPLIS data base is the parcel identifier. As described in an earlier section of the Guidebook, alternative approaches may be taken to define the parcel identifier. It may be simply a sequential number. It may be based on map sheets. It may be based on coordinates for the parcel center or it may take other forms. The essential rule however is that it must allow each parcel to be identified uniquely. This parcel identifier must be recorded with all data that relate to a parcel. In the automated MPLIS it is possible to employ index tables that will allow cross referencing between identifiers. For example, some functions may identify data by an address and the MPLIS may relate the address in an index table to the parcel identifier for entry with the data, or for subsequent processing. The same principle holds for other features represented in the MPLIS. If there are records about road segments, transmission lines, or flood plains, they must be uniquely identified.

Other identifiers may be included to define individual records such as a permit number, case number, or others. These too may be included in cross index tables to allow the data to be related to other data at the same location.

The second data class includes data that provide the *basic characteristics of a feature*. For example, a parcel record could include ownership, size, use, zoning, and other characteristics that are frequently used by multiple applications. The actual contents of this class in a jurisdiction will be determined from the requirements of the various organizations that will share the MPLIS. These "core" parcel data will generally be stored in an MPLIS under the control of a DBMS to facilitate access by multiple applications.

The third class are data that are *specific to an individual module or application* and are not shared among numerous applications or are not shared often. They will generally be managed in separate data sets, though they may be managed by the same data base management system as the core data.

An example of the structure of an MPLIS data base reflecting these three classes is given in Table 21-3.

TABLE 21-3
DATA CLASSES

Class	Data Elements			
Class 1	Identifiers			
Class 2	Core Data	Parcel no.	Address	owner, size, land val, imp val, land use zoning, ...
Class 3	Registrar	Parcel no.		book, page, date filed, ...
	Tax	Parcel no.	Address	bldg. type, rooms, condition, appraisal date, ...
	Bldg Perm	Parcel no.	Address	permit no., type, applicant, date issue, inspect status, ...
	Rezoning	Parcel no.	Address	case no., exist zone, req zone, applicant, date status, ...
	Subdiv	Parcel no.		case no., number of lots, ...

The full range of data managed by a comprehensive MPLIS can be very broad. Automation of that data will require an extensive planning and design effort to provide an effective structure that will maximize the benefits of the MPLIS. Automation must deal with many aspects of data that single use paper records do not address.

The conversion of data to digital form raises a set of issues such as opportunities for assignment of codes in place of lengthy descriptions. The automation requires a high level of standardization in the way that information is recorded. Such standardization is not essential in paper records that will be read and interpreted by human beings. Discussions of data standardization and its relationship to data quality can be found in Chapters 9 and 20. The opportunities for sharing data bring requirements for identification schemes and standard definitions in an automated environment. The management of a complex, wide ranging set of data brings requirements for data management that far exceed the requirements for single organization files and records. The great potential for benefits from automation therefore bring with them many requirements of the MPLIS.

The data base for the MPLIS will be defined in terms of a data model. The data model provides the specific structure for the data to be incorporated into the automated MPLIS. It should define the contents of the data base and the relationships among each of the elements and how data "flow" through the system. These data must finally be defined in terms of the specific software or programs acquired or developed for the MPLIS. See Chapter 10 for a discussion of data objects, linkages, and data base models.

MODULES

While automation of an MPLIS may involve use of any of the hardware and software components previously identified, the combination of these components to support a specific function is defined for the purposes of this Guidebook as a module. The modules of the MPLIS are specific operations performed by the MPLIS to provide support for user functions. The modules are specific implementations of combinations of the components that address an individual land information function. Typical MPLIS functions include:

Deed Registry
Tax Assessment
Permits (building, occupancy, demolition, well, septic tank, health)
Development Administration (rezoning, subdivisions, site plans, variances)
Infrastructure Management
Emergency Services (E911, police, fire)
Inventories
Mapping

These functions may be organized and their bounds defined differently in each organization, but functions of this type are performed by most local governments. The module is a specific combination of the use of the hardware devices, operating system, a specific DBMS schema, and procedures defined in some combination of the 4GL, macros, utilities, and programming language. The module is typically installed to satisfy the operational requirements of a department or division. In a modern MPLIS they will draw on shared data from the common DBMS and may manage additional data specific to the module. The module will support:

Entry, verification, and editing of data;
Permanent storage of the data;
Retrieval based on standard retrieval keys or combinations of selection criteria; and
Preparation of displays on a CRT or paper reports.

The module may also include various processing operations to combine or relate data, to calculate values, or to perform other specific computations that may be required.

MPLIS TIME DIMENSIONS

Several aspects of the time dimension are significant to the automation of an MPLIS. One aspect is existing data and their role in the implementation of an MPLIS. All relevant existing land data may be entered to create the MPLIS data base. Alternately, existing data may be ignored and the automation may incorporate data from an implementation day forward, with no capture of previously existing data for the data base. Often, a portion of existing data may be converted to the MPLIS data base as its operation is initiated. The portion to be incorporated, for example, may be cases or procedures that are active as the MPLIS is implemented. A different approach would be entry of data for selected activities such as rezoning or subdivision cases. A third alternative might be entry of data to a specific past date such as 1 year. Some combination of these alternatives also might be used. The decision on the timeframe will be based on the requirements for the MPLIS, the condition of existing records, the availability of historic data, and the costs or resources available for data base development.

Another aspect of the time dimension to be considered is the issue of archiving historic or outdated data. It may be valuable or necessary to save some types of data in archive files when they are replaced by changes. The most obvious data to require archiving are parcel ownership and characteristics such as parcels that are split or recombined. It may also be useful to archive permits, development cases, or other data to support analyses of development patterns or to verify past conditions.

The time frame for archiving is also an important time dimension aspect. Will data be archived and available on a continuous transaction response basis as changes are made or will data be archived on a regular periodic basis such as quarterly or annually? A decision must be made in the latter case between archiving all data as of the periodic date or just data that have been replaced as of the date. The former approach poses a more complex data management problem, but will allow retrieval of data for specific dates, while the latter will only allow recognition of time on the periodic cycle. The latter approach may also require greater data storage capacity if the full data set is archived at each cycle. Decisions about which approach to choose are generally application dependent.

Another aspect of time to be considered in MPLIS design is the time frame for entering and updating data as changes occur. In many cases immediate or "real time" updates are required or desired. In some cases, however, the cost of immediate update may not be justified. In others it will not be necessary or even appropriate. In most cases, some lag time will occur as the process occurs and a gap from "real time" is inevitable.

SPATIAL SIGNIFICANCE

An important aspect of an automated MPLIS that differentiates it from other automated systems is its spatial or geographic significance. All data recorded in and processed by an MPLIS are related to a spatial location. That spatial dimension is very important in much of the processing of data in an MPLIS. The precise location in the jurisdiction is important to many land related decisions. The proximity, connectivity, adjacency, or other spatial characteristics are also important to much of the land-related decision making and information use. The MPLIS must therefore provide the capabilities to record location at a minimum, and spatial relationships in many cases, to achieve its full value to the jurisdiction.

Some spatial information and relationships can be encoded in the data through use of an indexing scheme or spatial relationship definition such as a topological structure. Most location and spatial-relationship definition, however, is dependent on use of maps or coordinate systems (many jurisdictions are using COGO, airphotos, etc.). Maps and other forms of spatial data portray the locations, relationships, and indexing schemes such as addresses or parcel numbers. A map therefore is an important component of an MPLIS. The automation of spatial data poses special requirements that cannot be met by conventional automated systems. There are requirements for special data entry devices capable of converting maps to digital form and specific output devices capable of displaying or plotting the intricate graphics of a map, and requirements for special software to enter, manage, process, and generate displays of map data.

Two forms of automated systems have been developed to process map data in an MPLIS. The simpler of the two is an automated map (AM) or computer aided drafting (CAD) system that handles the processing and storage of map data and production of maps, though this form provides little or no spatial analysis capability. The second offers the additional software to relate map and nongraphic data and to retrieve, analyze, and display data on the basis of map location and spatial relationships. This form of MPLIS is the one we have defined in this chapter as a GIS. Over the past several years, the GIS is becoming the most dominant and most significant component of an MPLIS. It adds the important geographic aspect to the MPLIS.

SUMMARY

Automation of the MPLIS offers opportunities to capitalize on the benefits of the system. Automation provides the mechanism for easy and effective integration of the multiple sets of data involved in an MPLIS and improves accessibility and processing of the data. Automation of the geographic aspects of the MPLIS through a GIS offers even greater opportunities for integration and for analyzing the spatial relationships among the various data components.

Automation of the MPLIS can take many forms depending on the requirements and resources of the organization. In most cases, automation of several modules of the MPLIS will already have been accomplished. In this case, the challenge is to provide linkage and integration to what were probably individually developed automated applications.

The range of technology now available for automation is very great, ranging from desktop personal computers to very powerful mainframe processors capable of simultaneous support on numerous functions and hundreds of users. The emergence of network technology has enhanced the ability to interconnect systems in the various land information offices in a local government to form a shared MPLIS.

This first chapter regarding automation has presented introductory information regarding automation of an MPLIS and introduced some of the key issues related to automation. The second chapter, Chapter 22, can be used for familiarization with the numerous components available for automation of an MPLIS. The third automation chapter will discuss the tasks involved in designing, developing, and implementing an automated MPLIS. In addition to the steps involved in development of an automated system, this chapter will provide guidance to the developer. A sample model automated MPLIS is described in the final automation chapter.

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APPENDIX 21-1
COMPUTER AND INFORMATION SYSTEMS ACRONYMS

AM/FM -	automated mapping/facilities management; a term used by utilities
Application -	a set of programs that perform a specific function or operation
CAD -	computer assisted dispatch system
CAD -	computer assisted drafting system
CAMA -	computer assisted mass appraisal system; used by tax assessors
Component -	a hardware device, software package, or other basic unit of an MPLIS
CPU -	central processing unit or computer processor
DBMS -	data base management system; commercial software for standard data management
DOS -	disk operating system; the most popular operating system of the PC
Geocode -	a geographic identifier assigned to a specific location or feature
GIS -	geographic information system
Module -	a combination of components and applications addressing an MPLIS functional area
OSF/MOTIF -	open system standards to facilitate communications linkage between computer systems.
PC -	personal computer, a class of processor with specific characteristics
RDBMS -	relational data base management system; a particularly flexible DBMS that manages data as tables or matrices
SQL -	structured query language for formulating inquiries of a DBMS
UNIX -	an industry standard operating system used by many vendors for workstations
4GL -	fourth generation language; an easily used language for formulating queries and reports

22 AUTOMATION COMPONENTS

Michael J. Kevany

OVERVIEW

The automated MPLIS is made up of numerous components. The precise set of components and their relationships should be designed and selected to meet the requirements of the MPLIS within the resources and operating environment of a jurisdiction. The developer of the automated MPLIS must evaluate the wide variety of available components, select the combination that most effectively satisfies the requirements of the organization, and integrate the selected components into an operating MPLIS.

This Chapter is structured to facilitate understanding of the components and their relationships and to facilitate the planning of an MPLIS. It should be noted that actual development of an MPLIS in any other than the simplest organization requires technical skills in information technology, land information issues, and application of an MPLIS within individual operating units.

The Chapter begins with a conceptual overview of the MPLIS components and their relationships. It then provides descriptions of the numerous components that may be used to compose an automated MPLIS. These components are organized into four groups here. Components are selected from these groups and integrated in a specific configuration to form an MPLIS as shown in Figure 22-1. The four groups are:

Hardware
Software
Data
Organizational Design (or Structure)

The Chapter concludes with a discussion of industry standards and a number of key automation issues involving alternative configurations or approaches that may be used to develop an MPLIS.

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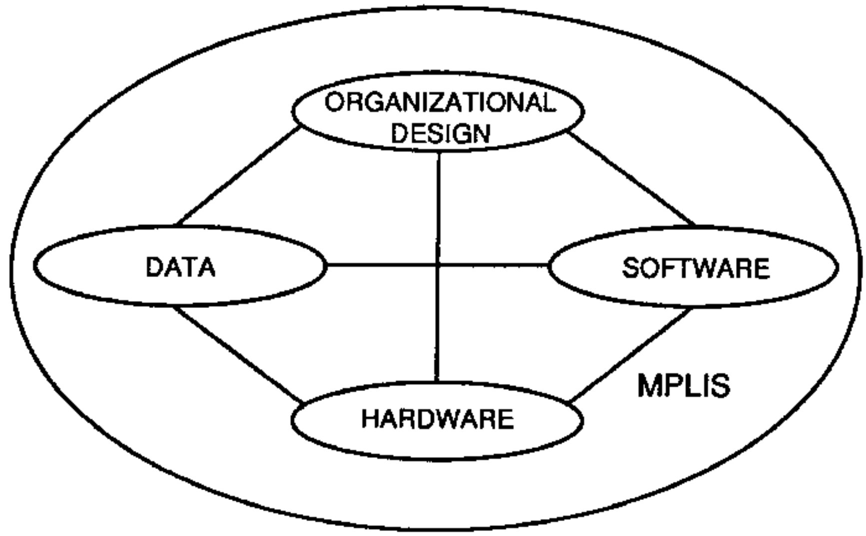

Figure 22-1: MPLIS Component Groups

COMPONENT CONCEPTS AND RELATIONSHIPS

Each of the four MPLIS component groups addresses a specific set of functional capabilities. Each of the groups plays a significant role in the operation of an MPLIS. Each must be configured to satisfy the requirements of the organization and the system users. Each must also be integrated with the others to provide the necessary operations.

The *hardware component group* is comprised of all physical devices that are used to enter data, perform processing operations, store data, operate the system, and generate necessary products. The hardware devices also include peripheral devices for system operations and communications devices used to interconnect all system components. Generally the hardware group consists of:

Processors, or the computers themselves;
Input devices, such as terminals, keyboards, digitizers, scanners;
Mass storage devices, such as disk and tape;
Output devices, including printers, monitors, and plotters; and
Communications devices, composed of controllers, cables, and modems.

The hardware devices provide the platform on which the MPLIS operates. The many operations of the MPLIS are performed on the hardware platform under the control of the system software. The hardware and software must be closely integrated for efficient operation. Traditionally, each hardware vendor provided a specific set of software to operate each hardware type. While many systems still provide this "proprietary" approach to hardware/software integration, there has been a recent move toward what is termed "open architecture." In this approach, the software is developed to a set of industry standards that will allow it to operate on multiple vendor hardware devices or platforms. By use of industry standards, the software becomes more hardware and vendor independent. This approach also facilitates integration of devices from multiple vendors in a single configuration and frees the users from having to learn and support multiple software packages for the individual systems.

The *software component group* is also comprised of multiple components. The software packages/capabilities that are most important to an MPLIS are the mapping/spatial analysis packages that are supported by Relational Data Base Management Systems (RDBMS). These specialized programs are supported by the more basic software -- the operating systems that manage the computer operation and control the data. The operating systems include one or more programming languages such as COBOL, FORTRAN, or C. Since commercial software typically comes already compiled, the use of these languages is transparent to the user. Most often, the software package includes a macro language or other kinds of custom programming tools that can be used by the developer to refine the MPLIS.

In addition, an MPLIS includes utility programs to perform standard operations; possibly a general purpose spreadsheet, wordprocessor, and graphics package; and possibly special Geographic Information System (GIS) or statistical analysis packages. In addition, the MPLIS may incorporate specific application programs or packages for registry, computer-aided mass appraisal (CAMA), or other functions.

The software is selected to satisfy users' requirements and may come from multiple sources including the hardware vendor, specific software vendors, third party developers, internal staff, and consultants. Software should be selected based on the functional requirements of the system. Software selection should take precedence over hardware selection. Note, however, that in some cases, software comes "bundled" with hardware platforms.

The *data component group* may be limited to a single data set or may include numerous sets of a wide variety of data types. The data group will contain data describing the individual parcels in the jurisdiction. These data may be organized in a comprehensive parcel file or data base or may be divided among files or data base tables for individual application areas. Further detail on parcel data files can be found in the discussion on multipurpose cadastre in Chapter 21. The MPLIS data component may include graphic map data as well as conventional tabular data.

The final component group, *organizational design (or structure)*, provides the human and institutional components of the MPLIS. This group includes the organization established to develop, manage, maintain, and use the MPLIS and the staff assigned within the organizational structure to MPLIS functions. Like the other component groups, the organizational group may take numerous forms, ranging from a centralized department that provides MPLIS services for all system users to a decentralized structure in which each of the user units operates the MPLIS in support of its own functions. The staff of the MPLIS may range from a single person in a very small installation to many persons with numerous specialized skills divided among a multitude of assignments. Institutional and personnel aspects of an MPLIS are also discussed in Chapters 8, 16, and 17.

HARDWARE INTRODUCTION

Hardware components are electronic devices on which an automated MPLIS operates. The hardware includes computers and related peripheral devices for entry, processing, analysis, output, storage, and communications. The following are descriptions of the individual hardware components.

PROCESSORS

The processor, often called the CPU or Central Processing Unit, is the computer through which the automated MPLIS will operate. A variety of processors are available for use in an MPLIS, ranging from very large capacity and powerful mainframe systems capable of supporting hundreds of users simultaneously and numerous applications of all types to small inexpensive micro or personal computers (PCs) operated by one person. Between these are many types of micro, workstation, mini and super-mini processors with a potentially wide range of capacities. Also included is the server, which functions as a processor and storage device.

The processor is the main control for the system, performing or controlling the various functions of the system. An MPLIS may consist of a single processor or may be a combination of multiple processors operating independently of each other or integrated into a network through which commands and data may be transferred between processors.

While automation of an MPLIS may be possible within the existing capacity of the current processor or processors, most jurisdictions will find it necessary to upgrade existing processors or acquire a new processor or processors to satisfy the requirements of the MPLIS.

Characteristics that are important in selecting the proper processing components of an MPLIS include: compatibility with previously selected software, the number and location of potential users to be supported, the processing speed, and main memory capacity. Processing speed is often stated as Millions of Instructions Per Second or MIPS, but other measures are also used and no measures are universally accepted. The most important criteria may be operational speed or throughput, a very difficult criteria to measure prior to implementation.

PCs as MPLIS Processors

The PC has emerged as an important MPLIS processor. For the smaller jurisdiction, or an individual organizational unit within a larger jurisdiction, the PC may serve as the MPLIS processor. In a larger organization with a distributed configuration, PCs serve as nodes in the network, performing local processing for data entry or retrieval. In some configurations, data are downloaded from a host or server for local processing. In other configurations, the PC is used to retrieve and display data.

Several PC models are available with a wide range in processing power and speed. Where simple tabular-data display or entry is to be performed, a low end PC will be adequate. Where map or GIS data are to be processed, a high end, high performance processor will be required for the PC. The basic PC may also be augmented with boards for graphics processing or other functions.

In a stand alone configuration, the PC will generally operate word processing and data base management and/or spread sheet software for MPLIS processing. As part of a distributed network, the PC may also operate application programs or software accessed from the host or server.

Graphics Devices as MPLIS Processors

An automated MPLIS will often include automated mapping or geographic information processing capabilities. These capabilities will require special hardware devices for input and display of the map graphic images. The graphics workstation was developed to provide efficient processing and display of graphic data. The workstation is the primary point of operation of a GIS system. It supports interactive graphics processing, allowing the operator to request displays and to enter map features or modify displays interactively. Graphic data processing poses a special challenge because of the very large volumes of data involved. A graphics workstation has several components. Most graphics workstations incorporate a processor, though some, such as the device called an X Terminal, operate from the processing capacity of a separate host processor through a network. The processor is relatively powerful and fast and most are extremely powerful, operating at extremely high speeds. The workstation architecture has been especially designed for the demands of graphics processing, including coprocessors and other devices.

Alphanumeric terminals are not adequate for displaying map images. Therefore, a GIS also requires high resolution graphics monitors or display devices capable of adequately displaying curves and other map features for high quality maps. The display devices available today commonly support color display. The resolution of graphics monitors is referenced by the number of picture elements (also known as pixels) that can be individually addressed by software. Workstation monitors typically exceed 1,000 pixels in horizontal and vertical axes. Multiple sizes of monitors are available to suit varying requirements.

A keyboard for command and data entry and a mouse or other pointing device are included to support interactive operation. The graphics workstation has been designed for interactive operation and generally includes numerous functions to facilitate that operation.

The graphics workstation may include its own data storage device. The local data storage capacity may range from relatively minimal in support of graphics display and limited processing to a very large capacity in support of the downloading of large data sets for extensive processing.

Servers as MPLIS Processors

A relatively recent addition to the processing technology is the server. It has emerged as a significant device with the advent of the distributed network information system configuration. Under this configuration, a separate device on the network is dedicated to storing data, providing data base management, or providing other services, and, hence, "serves" the other devices on the network often referred to as "clients." As with the other devices, the server may take several forms with varying power, capacity, and operating speeds. The server is basically a processor and storage device that is used to store and manage data. The server provides various services such as file storage, data management, application processing, or high performance processing. For example, it may control the accessing of data, select data to be routed or downloaded to other devices in the configuration, and manage the entry or updating of data. The server manages a generally large capacity mass storage device. The server provides the capability to distribute data among various points in the configuration to maximize operating efficiency. The server facilitates the management of very large volumes of data that are common in an MPLIS. A common architecture is the client/server design in which the server supports devices such as workstations, terminals, plotters, and PCs. Figure 22-2 illustrates a typical client/server configuration.

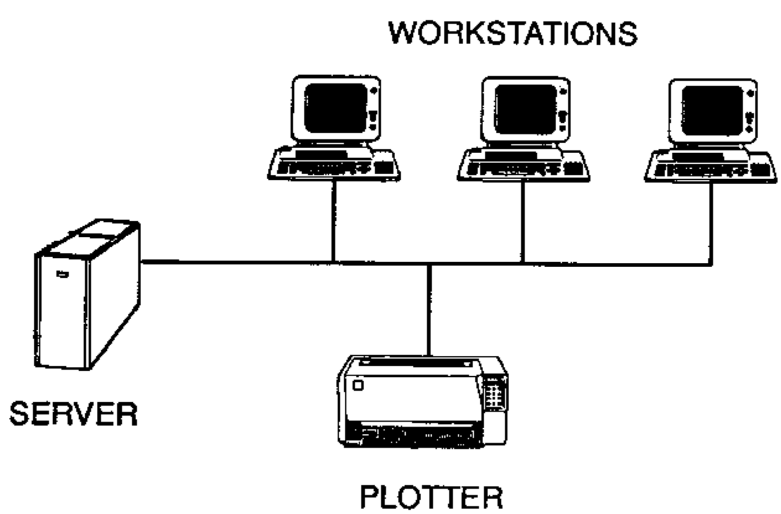

Figure 22-2: Client-Server Configuration

INPUT DEVICES

Terminals

Numerous types of terminals are available for use with computer systems. Most are composed of a keyboard and display screen and are used to enter and display alphanumeric data. Terminals are used to enter program code, commands for processing, and data to be stored and processed. They are a primary means for user access to the computer system. Some terminals have internal processing capabilities to perform functions directly, relieving the host processor of these functions. In many cases today, micro computers or PCs are serving as terminals, though special software and a network configuration may be required to support this approach. Terminals may also have graphics capabilities.

Digitizers

A digitizer is a tablet or table, much like a drafting table, that is used to convert map images into digital form. It does so by measuring the X and Y coordinates for the locations of the various points, lines, symbols, and text of a map. The source map is mounted on the digitizer and the scale, orientation, and other characteristics are registered in the system. The features of the map are then traced using a cursor that, with the table, measures the coordinates precisely.

Several sizes of digitizers are available to suit various purposes, ranging from the entry of map images described above to interactive operation with graphics images on the display screen.

Scanners

Another rapidly emerging device is the scanner. The scanner is a device that literally "scans" a document or map, recording digital values for the black, white, greytones or colors detected. The scanner typically generates data in raster format, that is, values for a matrix of individual grid cell picture elements, or pixels. Scanners operate in one of three ways. Either the scanning head moves across the document, the document moves across the scanning head, or some combination of these two procedures.

The resolution and optical characteristics of the scanner are significant to the quality of the image that can be reproduced digitally. For maps, a scanning resolution of 300 dots per inch is common, while for textual documents a much lower resolution is sufficient. Scanners designed for document scanning also have lens aberrations which result in uncorrectable distortions, making them unsuitable for precise map automation. The resolution impacts the density of data and storage and management capacities. A raster version of a map may consist of several hundred megabytes of data. An important aspect of raster data management therefore involves data compression. Several techniques are available for reducing the volume of data to be stored, while retaining the essential definition of the raster image.

While many documents can be processed and used in raster format as produced by the scanner, some data must be converted to vector format for use in a GIS, a process that is described elsewhere in this Chapter.

MASS STORAGE DEVICES

Tape Units

Magnetic tape is one media used to store digital data. Recent technology has evolved away from use of tape in operational processing, though it is still used as an important media in many existing computer systems. It is also an important media for off-line storage, back up storage copies of data and software, and transfer of data from one system to another. Most minicomputer, mainframe, and distributed systems include one or more tape units. Several types of magnetic tape units are now available, ranging from 9 track reel-to-reel tapes to 4mm and 8mm cartridges with capacities up to 2 gigabytes or more. The latter operate at a very high speed and have very large capacity. The characteristics to be considered in selecting tape units include compatibility with other devices in the organization, compatibility with data to be shared among agencies, copy speed desired, the type of device (e.g., reel-to-reel, reel-to-cartridge, etc.), device reliability, and stability of technology.

Magnetic Disk Storage

Most systems currently use magnetic disk storage devices as their primary mass storage medium. Disk storage supports very rapid random access to data and the units have very large data storage capacity of as much as several gigabytes. Disk units in operation include types that have removable disks or disk packs, though current systems are being implemented with fixed disks.

Optical and Compact Disk Storage Media

With the advent of very large data bases, and especially with the growing importance of image and document management systems with very large volumes of raster data, optical disk technology has been developed as a mass storage solution. In this media, the data are stored on disks by a laser etching process. This media has the capacity to efficiently store extremely large volumes of data on very small devices. Most devices are based on read only use, hence the common name WORM (write once, read many). Unlike magnetic disks, the data cannot generally be erased or replaced. (Some erasable optical disks have recently become available). With WORM devices, the data are recorded permanently on the disk. Several optical disks may be managed by a device called a "jukebox," capable of storing hundreds of gigabytes of data. Recent developments are expanding the flexibility of this basic media to allow read and write capability.

Another similar technology is the compact disk (CD), often called CD ROM (compact disk read only memory). Like the WORM devices, the data are permanently recorded on the CD ROM. This media is used for data distribution rather than internal storage and management. It is a very high capacity and low cost means of distribution of data or software, that is particularly cost effective when many copies of a set of data, such as U.S. Bureau of the Census data, are to be distributed. Since it requires "mastering" of an initial copy, it is used where many copies of the same data set are to be distributed.

OUTPUT DEVICES

Printers

A wide variety of printers are available to produce permanent copies of listings, reports, and other products from the automated system. Various technologies are employed that provide a range of speeds, print quality, size, and production flexibility. Dot matrix printers are low cost devices useful where there are requirements for high volume printing or distributed printing. Laser printers are more expensive but produce higher quality products and can be used for graphics output.

Plotters

Plotters are the devices used to produce permanent copies of maps. There are several types of plotters using various technologies. The most common type is the *pen plotter* that uses a ballpoint, felt tip, or liquid ink pen to produce the map. This type is relatively slow but inexpensive and can plot on several media including paper, velum, and mylar. Another common form is the *electrostatic plotter* that uses a fine resolution of dots to produce plots. The electrostatic plotter is capable of very high speeds and produces color fill or shading more efficiently than pen plotters. Both types can plot in color and in very high resolution. Several sizes of plotters are available to satisfy various requirements. The electrostatic is significantly more expensive than the pen plotter. Other plotters available include: color and black and white laser printers, ink jet plotters, film writers, and thermal wax plotters. A third type of plotter is generally called a *screen copy device* because it produces a hardcopy version of a screen image at the press of a button. It is used for quick plots, not to scale, at 8 1/2" x 11".

COMMUNICATIONS DEVICES

The distributed configuration is dependent on an efficient communications network and devices. The communications system may consist of both local area networks (LAN) and wide area networks (WAN). Each of the nodes in the distributed configuration must be linked to the other nodes through the network. The LAN supports very high transmission rates among devices within a single building or in adjacent buildings. The WAN is used to connect remote locations. The WAN uses facilities of a telephone or communications company, often over a dedicated broadband or fiber optic cable.

Several configuration topologies are used, each with its advantages and disadvantages. Three common topologies are *ring, star, and linear.* As the names suggest, the ring connects pairs of devices in a closed circuit or ring as depicted in Figure 22-3. The star configuration has all nodes connected to all others (Figure 22-4) while the linear (Figure 22-5) has devices connected to a central or backbone communications line to form a linear configuration. Each configuration must include mechanisms for controlling the movement of data through the network, eliminating "collisions" and detecting errors.

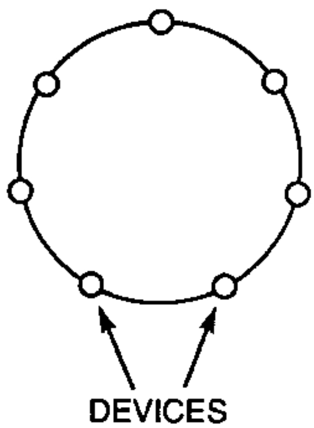

Figure 22-3: Ring topology

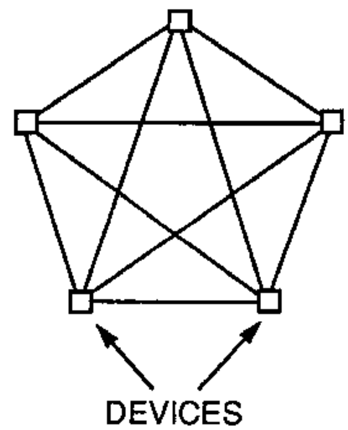

Figure 22-4: Star topology

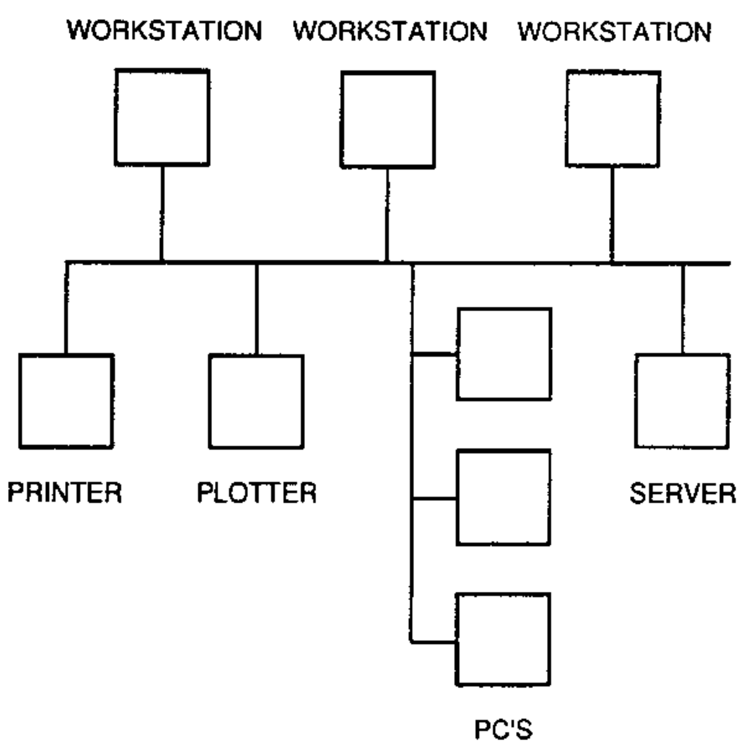

Figure 22-5: Linear (backbone) topology

The communications network is comprised of several components. Terminal servers are used to connect multiple devices to a LAN, transmitting and receiving signals over the network. Modems are devices that translate the digital data into analog electronic impulses for transmission over telecommunication lines and for re-translation into digital data for reentry into a processor or storage device. Digital modems or channel service units/digital service units (CSU/DSU) are used for high speed, high quality digital transmission. These devices do not translate to analog form.

The network itself is comprised of wires, cables, or fiber optics through which the data are electronically transported from one device to another. The various media have differing capacities and operating speeds or transmission rates.

The communications network must also include a controller or processor to support the operation and management of data as they move through the network.

HARDWARE SYSTEM CONFIGURATION

The MPLIS hardware configuration can take several forms. The three most common are depicted in Figures 22-6, 22-7, and 22-8. They are the *centralized, distributed network, and independent processor configurations.*

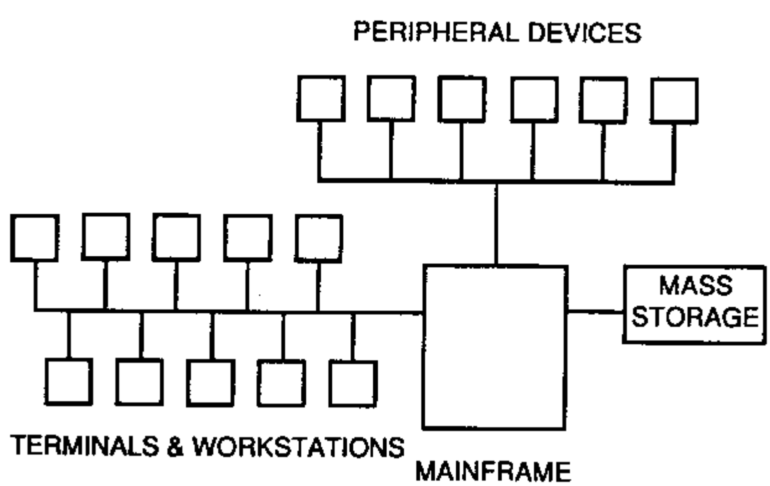

Figure 22-6: Centralized MPLIS Configuration

The *centralized configuration* (Figure 22-6) is based on a host processor or mainframe that supports terminals and other peripheral devices at user locations. In this configuration, all the software are resident on the host and all or most processing occurs on this device. The central configuration also includes a central mass storage device or devices on which the software and all data are stored. The central mass storage device(s) operates under the direct control of the host processor. The terminals, printer(s), and other devices in this configuration are typically wired directly to the host, though some may operate from remote locations through modems and a telecommunications system.

In the case of the *distributed network configuration* (Figure 22-7), multiple processors and storage devices are linked through a communications network. Also on the network are terminals, workstations, printers, and other peripheral devices often referred to as "nodes" on the network. The distributed network allows users on the network to access or share the resources of the network, including hardware devices, software, and data. If one processor is down or lacks capacity for a task, the processing requirement is shifted to another processor node in the network.

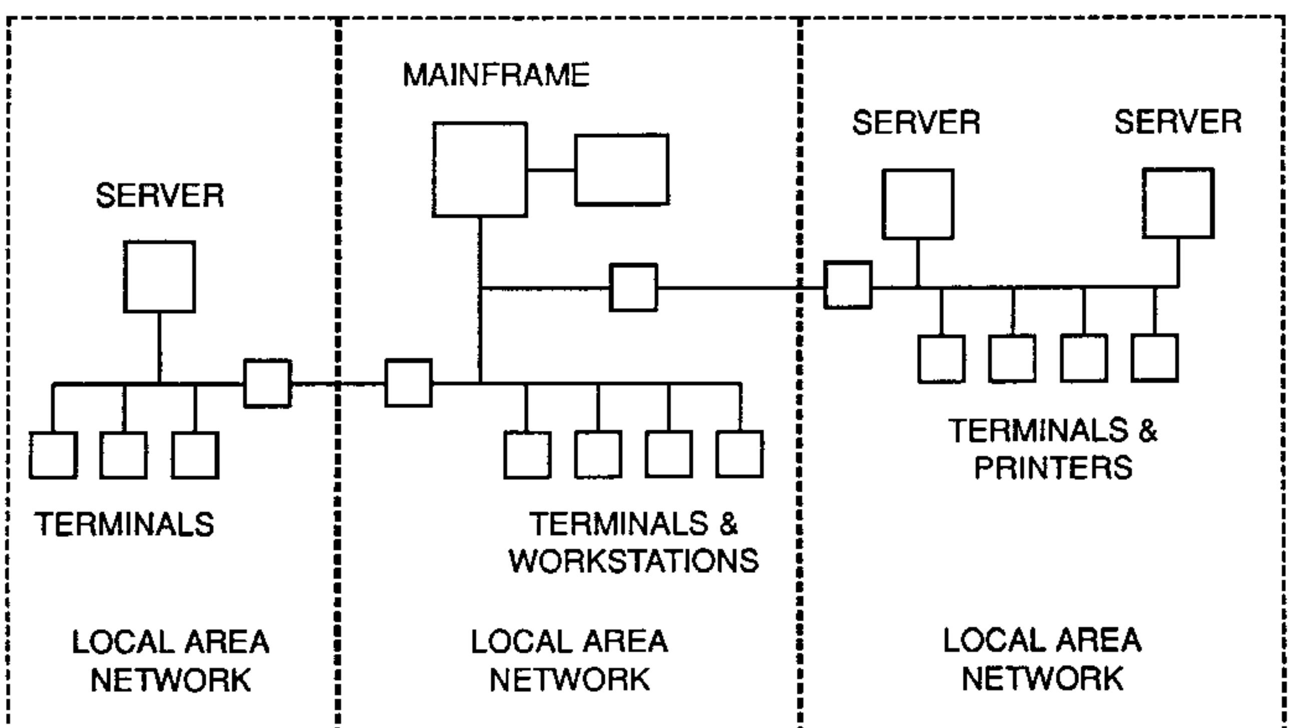

Figure 22-7: Distributed MPLIS Network Configuration

Similarly, the data can be stored in multiple locations throughout the network. When a user requires data, the network management software is used to locate and access the required data from the device on which it resides in the network. Within the limits of the system security, all nodes in the network may have access to data or processing resources at any node in the network. A relatively recent development in network architecture is the use of servers as special processors and mass storage devices that are dedicated to providing data base management for the network. This latter approach is termed a client/server configuration.

The third hardware system configuration alternative is the *independent processor configuration*, illustrated in Figure 22-8. This configuration is a single PC in its simplest form or may be some combination of PCs, mini computers, and/or mainframe processors, each operating independently of the others. Typically in this approach, each department or function has its own independent computer system. This approach does not support on-line sharing of data or resources, except by special arrangement.

The design of hardware configuration must consider many characteristics of these devices including capacity, operating speed, display, and hard copy quality. Each device has its own set of specifications or characteristics that will be analyzed in the design process. The combined characteristics of the configuration must also be analyzed. The efficiency of operation and the quality of throughput considering all components in the configuration are important to the design of an automated MPLIS.

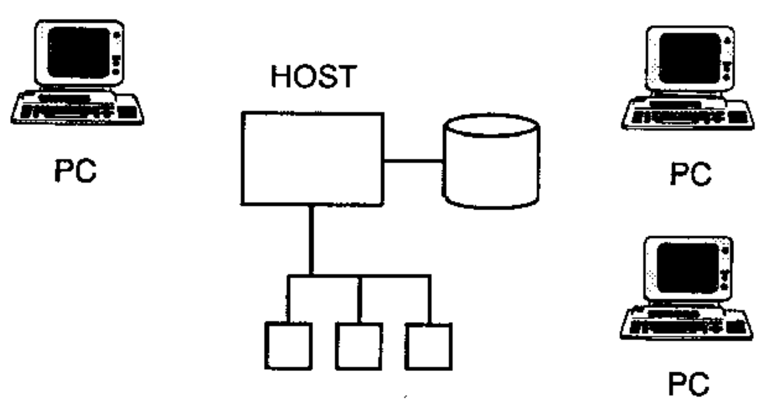

Figure 22-8: Independent Processor MPLIS Configuration

SOFTWARE

Software components provide the logic for operating the automated MPLIS. The software includes, but is not limited to, the operating system, the DBMS, programming languages, application programs and development tools, and commercial program packages.

OPERATING SYSTEM

The operating system is generally provided by the system vendor and performs the basic processing capabilities of the system. The operating system manages all system resources and provides the basis for all software components. Operating systems may be unique to the particular hardware processor, may be part of a family that manages a line of processors provided by a specific vendor, or may be a hardware independent industry standard. The latter are becoming increasingly popular and are intended to increase flexibility in configuring a system and integrating multiple processors in a network. The most common industry standard today is UNIX for a wide range of processors. DOS for the PC has become an ad hoc standard because of the popularity of the PC.

DATA BASE MANAGEMENT SYSTEM (DBMS)

A DBMS is a software package used for standard input, storage, retrieval of data, and production of reports. The programmer or operator of the DBMS defines the structure and items desired for the system in a schema according to a data definition language (DDL) provided with the system. Data are then loaded or entered into the system in accordance with that definition. As data are to be retrieved and displayed or reported, the operator uses a procedure provided to specify the data to be selected, combinations or tabulations to be performed, and the contents and format of the terminal display or printed report. The DBMS provides very powerful capabilities for information processing without requiring special programming. It is particularly useful in an MPLIS where it supports storage of data independent of application programs and use by multiple organizations in the format and combination required for each.

Numerous DBMSs are available in the marketplace. Some have been specifically developed for the PC, while others operate on workstations, servers, and mini or mainframe computers. Some DBMS vendors also provide a family of packages that operate on a range of processors, providing transportability and interface between differing processors in a configuration.

The most common type of DBMS is the *relational DBMS*, referred to as RDBMS. In the relational data model, data are stored in two-dimensional tables allowing the definition of multiple relationships between data elements as needed. Other data models used include the *hierarchical* and *network* data models. In the hierarchical data model, data are stored and controlled on the basis of a one-to-many, i.e., parent-child relationship. In the network data model, data are stored as group types in conceptual files in sets of one-to-many or many-to-many relationships.

A key industry standard issue of the DBMS is the use of the Structured Query Language or SQL. SQL has emerged as an industry standard query language for RDBMS. Several vendors of systems make use of SQL, thereby providing a means to facilitate communication between systems and easing the requirements for learning multiple query languages (see Figure 22-9).

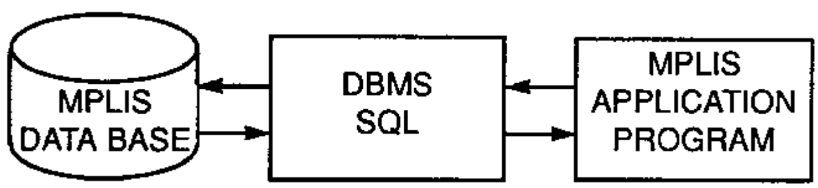

Figure 22-9: Role of DBMS in MPLIS

PROGRAMMING LANGUAGES

Several programming languages are available, including COBOL, BASIC, FORTRAN, and C to allow users of computer systems to develop application programs that perform the specific operations required. Each language has various advantages and disadvantages relative to specific requirements and environments. Some, such as BASIC, are relatively easy to learn, while others require extensive specialized training.

APPLICATION DEVELOPMENT TOOLS

The MPLIS will make use of a set of application development tools provided by system software vendors. The development tools are used to create easily used applications for the system clients (Figure 22-10). The tools generally include the following basic components:

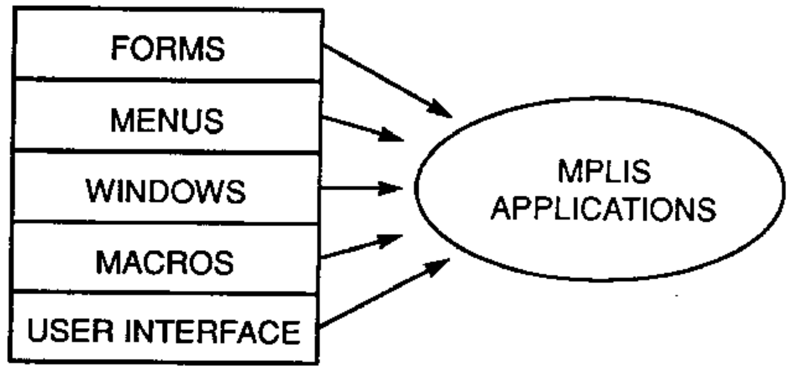

Figure 22-10: Application Development Tools

Forms are used to format displays for the entry of data and for display of standard reports. The forms tool allows a developer to easily define forms for display with underlying rules for the insertion of data entered through the form into the proper data base location and for the placement of data for output report display.

The *menus* tool is used to format operator interaction menus. The tool supports the placement of menus, the labeling of menu command prompts to users for further input, and the linkage to invoke commands selected from the menu.

The *windows* tool is used to select windows for display. It allows the developer to show multiple displays and run multiple processes simultaneously.

Macros are procedural commands that can be combined to form application procedures. The macro language is generally easier to use than a programming language and effective for generating applications that can make use of standard commands.

The *user interface* is an important application development tool that supports window management, icons, on-screen buttons, menus, and dialog boxes.

APPLICATION PROGRAMS

Application programs are developed to perform specific operations. They may use the DBMS, SQL, the application development tools, or a combination to produce procedures that are optimized for specific functions. Some standard application programs are available for purchase from vendors, relieving the user of the effort, time, and expertise required for development.

COMMERCIAL PROGRAM PACKAGES

Commercial program packages are a form of application programs or systems that are acquired as an integrated package that includes some combination of hardware, software, installation, training, documentation, and maintenance. Typical functions for which commercial packages are available include:

CAD
GIS
CAMA
Document Management
Spreadsheet
Word Processing
Statistical Analysis
CASE

A discussion of each of these follows in the next section of this Chapter.

In some cases, the term "turnkey" is used to suggest that the system can be installed and operated with a minimum of system modification, tailoring, or additional development. This approach can be a very cost effective and timely approach to system implementation. It may, however, pose problems for integration of individual modules into an overall MPLIS.

CAD

There are actually two types of software that operate under the acronym CAD. One is graphics processing software, Computer Aided Drafting, that is used extensively for engineering drawing and design and for automated mapping functions. It includes software for the digitizing of graphics images, management of the resulting graphic data, and display and plotting of drawings or maps. Unlike a GIS, described in the next section, the CAD software has minimal or no nongraphics attribute processing or spatial analysis (e.g., topological overlay) capabilities. It is used strictly to draft, update, modify, and display or plot images. This type of CAD system may be used as part of an MPLIS as a mechanism to convert map data to digital form for further processing in the MPLIS and as a graphics output capability to generate maps from MPLIS data.

The second type of CAD system is the Computer Aided Dispatch system used for emergency response dispatching, often as part of an E911 system. This CAD system receives the address of the call for service as input. It analyzes the address, matches it to a geographic data set, often called a "geofile," from which the proper response path or unit is determined. The CAD system may have additional capabilities to support locating the site and to provide additional emergency support information regarding the subject site. This CAD is closely related to an MPLIS through its use of address and geocode data. In many cases, the geofile of address and geocode data are maintained and updated through the MPLIS and accessed by the CAD.

GEOGRAPHIC INFORMATION SYSTEM (GIS)

As mentioned previously, maps and geographic locations and their spatial relationships are especially important to an MPLIS. The processing and display of maps and the retrieval and analysis of geographic information present special requirements for an automated system. Included in these requirements are needs for special spatial and geographic processing software.

There are two basic uses of mapping and geographic information systems. These are the automated production of maps and graphics displays and the retrieval and analysis of data on the basis of their geographic characteristics. Map production can be supported by relatively simple systems, many of which currently operate on a PC. Geographic information processing and analysis, on the other hand, generally require a more sophisticated system of greater capacity, though PC systems are available and are becoming more common.

The GIS has special capabilities to process both graphic (map) and nongraphic (tabular) data and the combination of both. Like a CAD system, the GIS can maintain and produce maps. In addition, the GIS can manage, maintain, and report nongraphic tabular data. The GIS supports the retrieval of data by location, geographic conditions, or attribute selection criteria. It can display selected data as a map with appropriate features highlighted or colored, or it can display a tabular report. The GIS also records the spatial intelligence in the form of topological structures of adjacency and connectivity, feature types or layers and, in some systems, objects and relationships. Using this intelligence, the GIS can perform polygon overlaying and analysis, network route and flow analysis, facility service area analysis, proximity analysis, and other functions.

The GIS configuration is made up of some special graphics-oriented hardware devices and other devices common to all information systems. Graphics workstations, described earlier in this chapter, are the primary GIS devices. The GIS also requires digitizers, and plotters, and scanners.

The GIS uses the standard RDBMS described earlier for management of the nongraphic data. The RDBMS used may be the same one used for the overall MPLIS or a separate RDBMS may be acquired with the GIS. In addition to these standard components, the GIS includes special spatial analysis, graphics data management, and application development software. These tools provide the capabilities that differentiate the GIS from other system components.

The GIS is intended as an end user tool. As such, it is necessary to develop specific user applications for each function. The technology is too complicated for a person to master without extensive training and practice. The development of applications, however, enables a person to make use of the GIS for a specific operation with very minimal training.

The operational tools of the GIS include:

map entry and edit
map display and manipulation
area/district calculation
query on geographic location
query on attribute characteristics
query on spatial relationships
tabular data reporting
terrain analysis
polygon analysis
network analysis
routing analysis

The first two will be discussed here.

Map Entry and Edit

GIS systems store descriptions of maps in a digital cartographic data file as the measured values of the X and Y coordinates of points or lines, the rules for generating map features, or the values for a raster image for a map. GIS systems also store and display the alphanumeric characters of annotation related to map features and symbols at their locations.

GIS software can be used in several ways in the measurement of map coordinates. Three methods will be discussed here: *manual digitizing*, *coordinate geometry*, and the use of a *scanner*. The most common method is termed *manual digitizing* and involves use of a digitizing table. The map to be converted to digital form is mounted on the digitizer surface and its origin, scale, and orientation are registered. An operator then enters the map features by pointing a cursor at points on the map and pressing the appropriate cursor button. Lines may also be entered by pressing the button while tracing along the line feature with the cursor.

Another method of entering map features is through a *coordinate geometry (COGO) program*. In this case the operator enters the location of the origin of a feature by keying its coordinates or by pointing the cursor and pressing a button. The bearings and distances of end points of a series of lines are then entered. The program interprets these data and calculates the resulting coordinates, generating the connecting line for display and storage. Property descriptions as recorded in deeds or surveys are often entered with COGO.

A third method of conversion of maps to digital form is use of a device called a *scanner*. The scanner uses one of various forms of optical, laser, and/or electronic devices to convert a paper map to digital form by recording values for the density of color or grey/black/white tones. This approach records the digital data as a raster format in which the values for a matrix of very small (e.g., 200 or 400 per inch) cells or "pixels" are recorded. This raster format can be use to reproduce the map for display or printing. For many types of processing, however, it is necessary to convert some of the raster data to a vector format; that is, to store the coordinate values for points or the beginning and ending of lines. This may be done by an automated process or by a manual editing process. The scanner has the advantages of being very fast in converting maps to digital form, very accurate for reproduction of the map image, and minimizing labor requirements. The disadvantage for much of the data is the effort required to convert the raster data to vector format.

Map Display and Manipulation

A recent development in standard GIS technology is the integration of raster and vector data processing capabilities for map display and manipulation. This allows the display of combinations of raster and vector images. For example, a raster-format orthophoto may be displayed as the base over which vector lines (such as parcel boundaries) and symbols (such as hydrants) are displayed. This capability has expanded the functions of GIS significantly. The combined raster and vector processing may be divided into several categories.

The digital map data are generally stored in a manner that separates various feature types. This may be conceptualized as a series of layers in which each layer is composed of a homogeneous or related set of map features. See Figure 7-5 in Chapter 7 for a diagram of a typical GIS layering concept. Each set of features such as parcels, roads, or utilities is stored as a layer. This layering provides great flexibility by allowing the system to produce maps of any combination of features by selecting combinations of layers.

Another flexibility provided by an automated system is the adjustment of map scale. The systems are capable of accepting map features in virtually any scale, combining them in the data base and displaying or plotting at any scale specified by the operator. This scaling capability must be used judiciously, however. The accuracy of data is related to the scale or accuracy of source documents. If the map is "blown up" to a larger scale, the accuracy will not improve in this process and will remain what it was at the smaller scale. The cartographic quality of a map will also suffer if large changes in scale are made.

Typical GIS systems also provide other map manipulation capabilities such as transformation of coordinates to control values (often called "rubber sheeting"), matching features along the edges of map sheets, and replacing less with more accurate coordinate values as they become available ("cut and paste").

Once the data are entered into the digital data base, they may be plotted as maps, displayed on workstation screens, or used in various forms of data retrieval or analysis. The most simple form is the display of either raster or vector images separately. In this case, the user selects either a raster or vector display to be generated from the data base.

The next level of complexity allows the simultaneous display of both raster and vector data in the same display. In this case, the vector data are typically overlayed on a raster background. Maintaining the positional registration of both sets requires special processing capabilities.

At the next level, image display with line overlay creates the ability to do "heads up" digitizing. That is, the ability of an operator to digitize a line along a raster image displayed on the workstation screen. This allows the creation of vector data as needed with a raster image serving as the background. It has efficiency not only in the flexibility of selecting features to be digitized, but also in the operator speed with which digitizing can be performed.

Advancing to the next level, automated generation of vector data from raster images is possible in a GIS with vectorizing capabilities. In this case, software are used to recognize the patterns of lines and symbols on raster map images and to generate coordinate values for the beginning and ending points of the line. Automated vectorizing may be performed in two modes. In one case, the operator selects a line in the raster image to be vectorized and the software follows that line creating vector coordinate values until the end is reached or some ambiguity in the pattern is encountered. The operator then selects the next segment to be vectorized or clarifies the ambiguity. The other mode is a fully automated batch operation in which the software attempts to generate vector data for all raster data features. This process must be followed by extensive operator editing and correction.

A final form of raster data management in a GIS is the integration of document management software that will allow an operator to select a feature or location on a GIS display for which a raster image of a document is to be displayed. The software will retrieve the correct image and generate a display in place of the map display or in a window provided in the display. This function makes use of the GIS as a selection tool and uses document management software for the indexing, management, selection, and display of the document images.

CAMA

The Computer Assisted Mass Appraisal (CAMA) system is a commercial package available for appraising the value of real property. The CAMA generally uses data maintained in a parcel or real estate data base. It requires data on the characteristics of land and improvements, including detailed data on building characteristics. The CAMA typically groups data by neighborhood or other area of homogeneous characteristics to facilitate valuation. The CAMA is supported with continuously updated data, such as sales price, maintained by the MPLIS. It may also use other MPLIS components such as the GIS to organize or display data.

DOCUMENT MANAGEMENT

Possibly the most significant recent development has been the rapid emergence of imaging and document management software and systems as a land records management tool. This software supports the scanning of source documents and generation of digital raster image data that can be stored on optical laser disk devices, the indexing of documents for automated retrieval, capabilities to edit and "clean" raster data, and capabilities for retrieval, display, and hardcopy generation. In many cases, the system is part of or integrated with a RDBMS that will allow retrieval of document images on the basis of a variety of search criteria. These capabilities are also being integrated with a GIS to allow the selection of images by pointing at map features or locations on a GIS display. The software will support the scanning and display of virtually any document, including text, diagrams, maps, drawings, and even photographs. It is important to note that analysis or precise measurement is not possible with imaging systems.

SPREADSHEET

Spreadsheet software, generally operating on a PC, manages data as a table or matrix. It is a flexible tool into which data can be entered and manipulated to create tables and to perform table or matrix based calculations. The software provides a basic structure and tools to allow the user to enter titles, data, and computation formulae. This software also provides simple tools for generating printed reports of the results. A key concept of this software is that it is easily used by persons who are not computer programmers.

WORD PROCESSING

Word processing software is now pervasive in local governments. It is often used as part of an MPLIS to generate standard reports and letters. A common application is the production of letters of notification of a meeting or action to be sent to property owners in the vicinity of a rezoning, subdivision, or other case. The software allows the user to easily enter, format, and process text. In some cases, textual data entered through a word processor can be "cut and pasted" digitally to form part of a product of a GIS or other MPLIS component.

STATISTICAL ANALYSIS

Several statistical analysis packages are available to perform virtually any statistical function on the data of an MPLIS. Many now operate on a PC and are easily used by non programmers. Data may be transferred or downloaded from the MPLIS data base for processing and analysis by the statistical software.

CASE

Computer Aided System Engineering (CASE) software is not specifically an MPLIS component, but may be used by the information services staff to develop and maintain MPLIS software. CASE is a set of automated tools that is used to design and develop computer programs, systems, or applications. The CASE set includes tools for analyzing requirements, diagramming data flows and relationships, and, in some cases, software that actually generates computer program code in an automated process from parameters supplied by other CASE tools.

DATA

The third major MPLIS group is the data. The next few sections will discuss data organization (i.e., the data base), data types, data classification, and data standardization. The reader should refer to chapter 8 as to types of land data and methods of acquisition. Chapters 1, 7, 9, 16, 20, and 21 also contain information relevant to the discussion of data for an MPLIS.

DATA ORGANIZATION

The MPLIS data base may be established in accordance with one of two basic models. One common model currently in operation is based on *individual systems and data files*. This approach is related to the use of COBOL programming as the common implementation platform. In this case, each module of the MPLIS is designed separately. The design includes both the computer programs and the data files to be used. The design defines input data specifications, processing programs, and the output reports to be generated. Programs in COBOL or a query language are developed to perform the necessary operations as designed. The system may or may not make use of a DBMS. Where a DBMS is used in currently installed systems, a hierarchical model is often used. However, an evolution is now in progress toward the RDBMS.

A second model is based on the concept that the various modules should make use of a *common data set*. The data are therefore managed by a RDBMS. The programs, applications, or systems in this case access data managed by the RDBMS. Most recent systems make extensive use of the programming languages provided with the RDBMS and what are termed 4GL (fourth generation languages) to simplify and standardize development. These higher order languages define procedures to be performed, input formats, queries and processes to be performed, and output displays or products. SQL has emerged as an industry standard, implemented by most vendors in a relatively standard manner to allow independence from specific vendors or devices. SQL is an easily used technique for specifying query and retrieval functions.

DATA TYPES

The data to be maintained by the MPLIS are of two basic types: tabular and graphics. The tabular data are recorded as alphanumeric characters and codes describing the characteristics of the various land entities, geographically referenced incidents, and their identifiers. The graphic data are the digital, computer readable descriptions of map features and images. The tabular data may be further divided into indices, core characteristics data, applications data, and/or geographically referenced data.

The map feature graphics images are converted to digital form by measurement of the X and Y coordinates of their locations in one of the commonly used coordinate systems, most generally the State Plane Coordinate System (SPCS). Using these data, the geographic information system component is able to generate maps on a display screen or plotter in accordance with specifications provided by an operator.

DATA CLASSIFICATION

MPLIS data can be classified into various categories. For example, one such classification scheme includes the following four classes:

Identification data (e.g., legal, administrative, and geographic),
Parcel data (index and description),
Map features or graphics data, and
Function or application data sets.

Location, geographic characteristics, identifiers, and therefore maps, are particularly important in an automated MPLIS since most MPLIS data are related to the land.

Identification Data

To facilitate retrieval of data efficiently, one or more identification schemes must be employed. In an MPLIS, location identification is particularly important, though other identification schemes are also used. The various location identifiers must indicate some combination of both geographic location and logical relationships between and among locations. Two of the most common identification schemes used in MPLIS are *street address* and *parcel number*.

The *street address* is easily used by both government officials and citizens. It defines geographic location through reference to the street system and must generally be supported by an index map that identifies the locations of addresses. While relatively easily used by humans, the address offers many problems for computer systems. There are problems with the misspelling of street names, confusion over different types of streets (e.g., street, avenue, lane, or boulevard), duplicate street names and sometimes addresses, arbitrary assignment of addresses by residents that don't conform to official addresses or assignment rules, and alternative names for streets (e.g., Main Street is also Route 10 or Pacific Coast Highway) that must be accommodated.

The MPLIS must include capabilities to match addresses from input records with official indexes, recognize and solve address errors, enter correct addresses in input records, and should include mechanisms for aggregating data based on address groupings (e.g., census tracts or police districts), and for mapping data by address location.

The second very common MPLIS identifier is the *parcel number*. The parcel number is assigned to all legally defined parcels in a jurisdiction and is used primarily for tax assessment purposes, though numerous other uses are made. A variety of approaches has been developed for parcel number assignment, though no universally accepted approach has emerged. Some common approaches include:

1. Map sheet and parcel number - The individual parcel number is composed of two components: the number of the map sheet on which the parcel lies and a unique number within this sheet. Variations include an intermediate block or other number to facilitate location. The intermediate number may be a quadrant or grid location within the map sheet, a city block, or some variation. (See Figure 22-11.)

2. X and Y coordinate pair (for a point at the center of the parcel) - The coordinates may be recorded serially (e.g., X 1234 followed by Y 1234) or they may be interleaved to indicate successively smaller rectangles.(e.g., X1Y1, X2Y2, X3Y3, X4Y4). The coordinates are generally recorded in state plane values for an MPLIS. (See Figure 22-12 for an interleaved example.)

3. Township, range, and section number - This system is used in a number of the 30 PLSS states (see Chapter 6). These identifiers are often used for parcels in the tax assessment and collection systems of local government. Less often they may be also referenced in the title description or abstract. For example, the Wisconsin Department of Revenue has adopted a 12-digit number for statewide use in parcel identification. A typical parcel number using the PLSS as a base is:

   02-08-09-36-11-1234-0

   where the groups of digits are determined as follows:

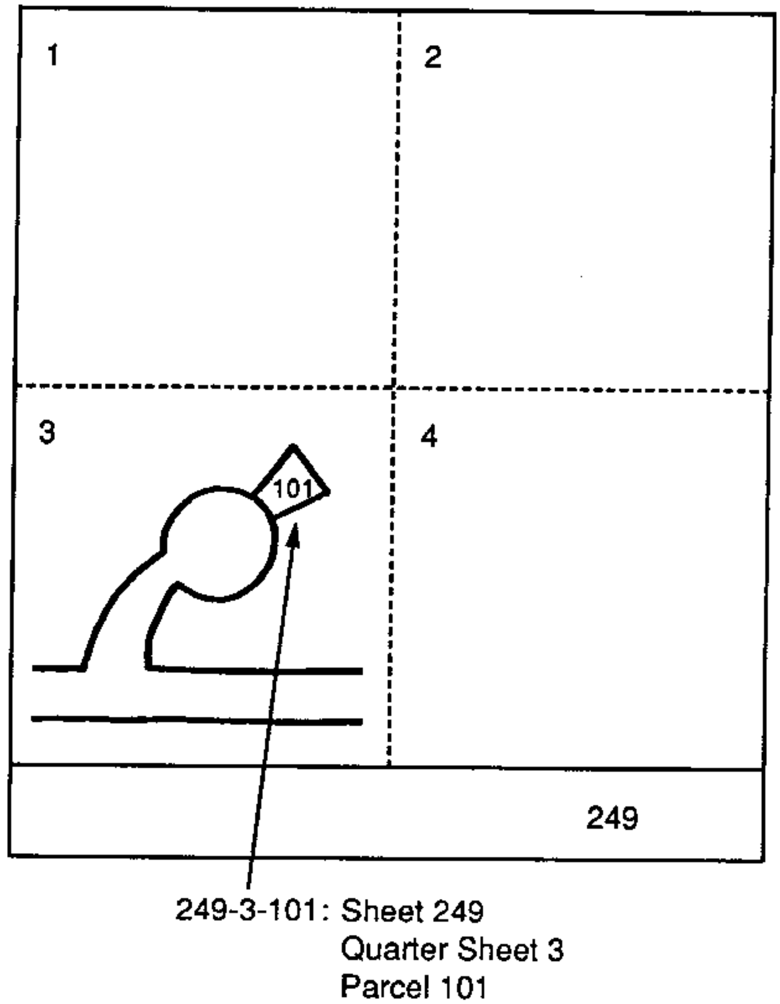

Figure 22-11: Map Sheet Based Parcel Identifier

- East or West of controlling Meridian (e.g., 2 = East of Meridian)
- the township number (e.g., 8 North)
- the range number (e.g., 9 East)
- the section number (e.g., section 36)
- the 1/4 section and quarter/quarter section number (e.g., the northeast quarter of the northeast quarter, numbered in a counterclockwise direction, starting in the northeast quarter = 11)

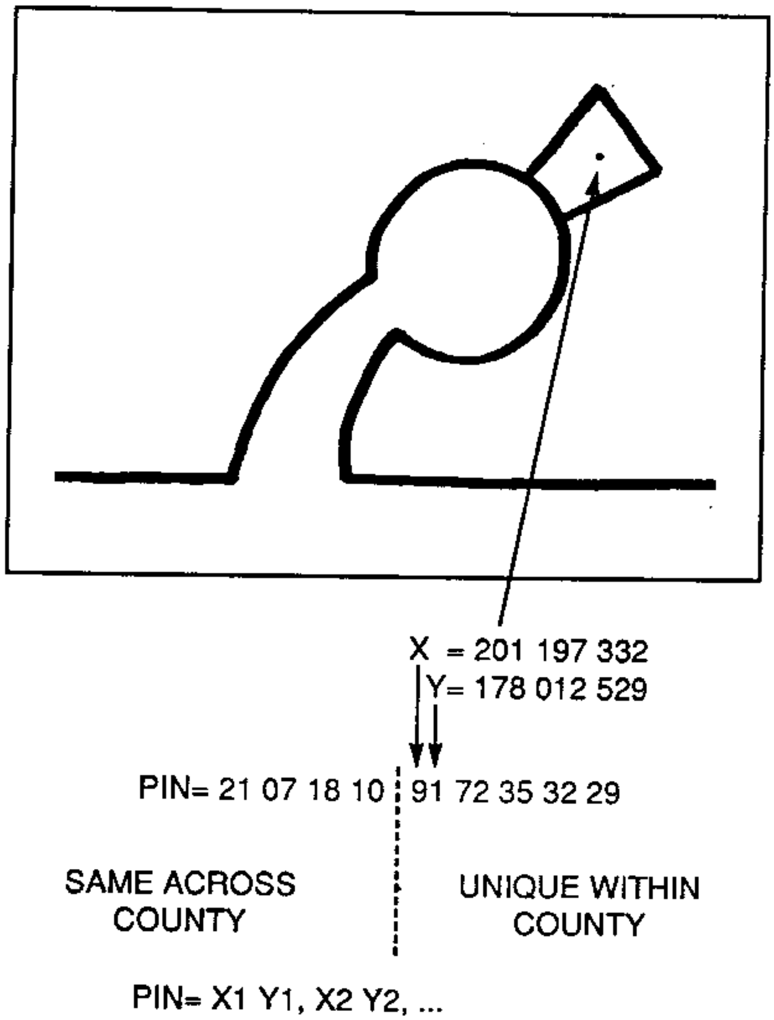

Figure 22-12: Coordinate Based Parcel Identifier

- a lot number (e.g., lot 1234)

- a check digit (e.g., 0), to guard against input errors, transpositions, etc.

4. Unique sequential number - In this case, the next number in sequence is assigned to each parcel as it is created. This approach provides no locational information without access to a map. (See Figure 22-13.)

There are various advantages and disadvantages to each of these and other approaches. While no national standard exists, the

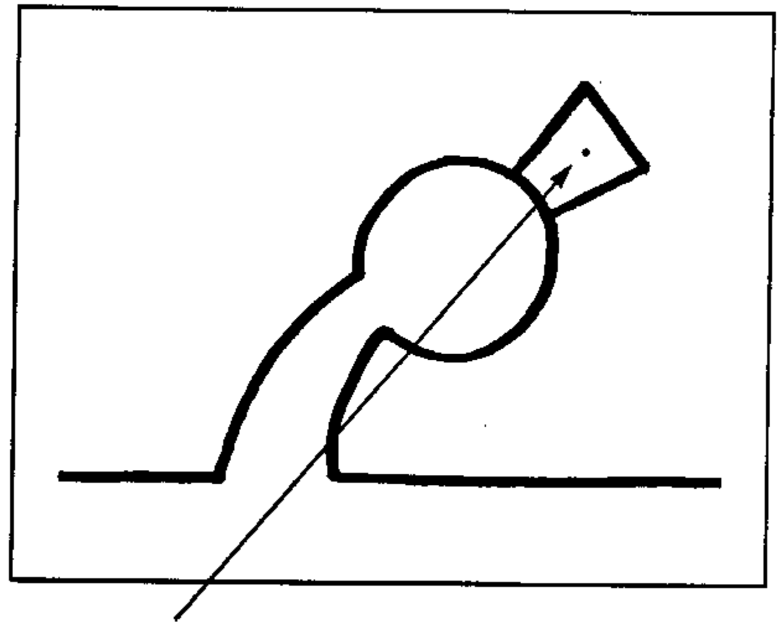

Figure 22-13: Unique Sequential Parcel Identifier

only universal requirement for the parcel number is that a unique number is assigned to each parcel in the jurisdiction. Many states at least recommend a standard parcel identifier, often through the state Department of Revenue or equivalent agency.

Geographic Base File (GBF)

Identification data often include the geographic base file, which is a set of all identifiers of geographic areas in the jurisdiction. This data set may or may not be a physical file, depending on the software acquired for the MPLIS. Conceptually, the GBF will contain one record for each segment or arc bounding a geographic area. In most cases, the records will represent street segments, but rivers, property lines, or any other elements bounding or dividing geographic areas may be used. For each segment or arc, a set of data identifying the element, defining its limits and orientation, and listing the geographic areas on either side will be recorded. The geocodes will be entered with "from and to" and "left and right" orientations relative to the segment.

The GBF can be used for any application that requires the verification or assignment of geographic codes, or geocodes, such as census block or election district. In most cases, the proper code assignment will be made on the basis of the street address, though any geographic locators contained in the file may be used. The GBF may contain the following data and geocodes:

From and To

- o Segment/Arc Number
- o Street Name
- o Street Direction
- o Street Type
- o Cross Streets 1 & 2
- o From/To Node Number

Left & Right

- o Address Range (high/low)
- o Block
- o Census Tract
- o Tax Area
- o Planning District
- o Municipality
- o Police Area
- o Fire Area
- o Emergency Management Service Area
- o Congressional District
- o State Legislative District
- o Commissioner District
- o Precinct
- o School District

Parcel Data

Parcel Index

The parcel index is a set of data containing all identifiers for each parcel. The index will have an entry for each parcel throughout the jurisdiction. The index will provide capacity for each of the possible identifiers used by, or of interest to, the various participating organizations.

Each parcel will be assigned a unique identifier. That identifier will become the parcel number as the jurisdiction implements the MPLIS. To preserve uniqueness, it will be necessary to assign new identifiers to all parts of a parcel when a parcel is divided.

The parcel index will be used by all parcel access applications to verify an identifier entered and to retrieve any other identifier(s) required by the application. Parcel index is also used more narrowly to refer to a tract index, which is a geographically-referenced claim of title system (as opposed to the name-oriented grantor-grantee index). The index will also be used by all applications to retrieve the unique parcel identifier used by the system to access parcel-related data sets. The parcel index may contain the following data items:

- Parcel Number
- Site Address
- Mailing Address(es)
- Place Name
- Parent Parcel Number
- Child Parcel Number(s)
- Subdivision/Lot Number
- Deed Book/Page Number(s)
- Subdivision Index
- Account Number
- Unit Number (Condo, apartment, commercial)
- Prior Account Number
- Owner Name
- Related Same Owner Parcel Number(s)
- Archive Index

Parcel Characteristics Data

Parcel characteristics data are a focal point of the MPLIS. This component will contain a comprehensive grouping of data describing the characteristics of each parcel. These data will be maintained on a regular basis in the system. This data component may be organized in various forms, depending on the software system acquired and the detailed design of the MPLIS. Conceptually, the component will contain a set of data for each parcel, including all of the descriptive information for that parcel. Related sets with information on basic parcel characteristics, tenure, value, history, buildings and units within the parcel, and tax status will be integrated through the parcel characteristics component. The parcel characteristics will be used by numerous MPLIS applications.

The core parcel characteristics data component can be further divided into seven sets as follows:

- Basic Parcel Characteristics
- Parcel Tenure Characteristics
- Parcel Value Characteristics
- Administrative Characteristics
- Building Characteristics
- Unit Characteristics
- Tax Status.

Basic Parcel Characteristics

The basic parcel characteristics set is at the core of the land information system. It is a set of data that will be shared by most applications. The data describe the basic characteristics of the land parcel, including its physical description, use, condition, and other characteristics. A list of basic parcel characteristics includes:

- Parcel Identifier
- Topography Class
- Area
- Road Class
- Frontage
- Non-developed Class
- Depth
- Mobile Home Code
- Land Use(s)
- Zoning(s)
- Number of Buildings
- Building Identifiers
- Number of Units
- Unit Identifiers
- Utilities Available
- Development Status
- Parking Spaces
- Well/Septic sites
- Swimming Pool
- In-Floodplain
- Slope Classification

Parcel Tenure Characteristics

The parcel tenure data set will contain information describing the ownership status and history for the parcel. This set will include entries for all owners of each parcel throughout the parcel's history. Candidate tenure elements include:

- Parcel Identifier
- Legal Description
- Owner Name(s)
- Prior Owner Names
- Parent Parcel Number(s)
- Child Parcel Number(s)
- Sale Dates
- Deed Book/Page Numbers (Current and Past Deeds)
- Easements
- Covenants

Parcel Value Characteristics

One of the major applications of the MPLIS is the tax appraisal function. Much of this application can be automated through a computer-assisted mass appraisal (CAMA) system. Appraisal requires a broad range of data that are used to compute real estate values. The CAMA will use data from all parcel characteristics data sets. The valuation data include:

- Parcel Identifier
- Commercial/Residential Code
- Land Values
- Total Value
- Improvement Values
- Sale Price
- Sale Date
- Prior Sale Prices
- Prior Sale Dates
- Agricultural Program Status
- Agricultural Program Value(s)
- Exemption

Administrative Characteristics

A local government performs various functions related to parcels for which information records are maintained. These administrative activities include rezoning, subdivision review, health, and other cases. Administrative records describing various incidents related to parcels are also created for emergency services and other functions. Indexes to these cases and incidents may be maintained in the parcel records to facilitate identification of information and activities on parcels. Data on each case or incident related to the parcel are recorded with an entry for each case or incident. These data are updated from the related administrative activities. The case and incident data may include:

- Parcel Identifier
- Administrative Case Numbers
- Permits
- Active Cases
- Active Case Status
- Development Conditions/Limitations
- Incident Identifiers
- Development Activity Codes

Building Characteristics

Building characteristics data are required for computer assisted appraisal procedures, as well as numerous other functions throughout a typical local government. A set of data will be maintained for each building and related to the parcel on which the building resides.

Unit Characteristics

Many parcels include buildings with multiple-occupancy residential or commercial units for which information must be recorded. The unit data will be used for automated appraisal, emergency response, and several other functions.

Tax Status

Tax billing is a vital function that is closely related to land records, relying on up-to-date parcel identification and ownership data for timely collection. The land information system will also include basic tax status data, usually as part of the value assessment (tax) system.

Map Features or Graphics Data

The map features data are stored by a GIS in the MPLIS and consist of the coordinates that define the graphics images of the map features, identifiers for each of the feature elements to link them to their related attribute data, and the spatial relationships between each element and the others. The following are typical map features that may be included:

- Parcel Boundaries and Annotation
- Subdivision Boundaries
- Rights-of-Way and Easements
- Streets and Street Names
- Zoning
- Municipal Boundaries
- Election Districts
- Precincts
- Emergency Response Districts
- Census Tracts
- Tax Areas
- Planning Districts
- School Districts
- Water Bodies
- Floodplains
- Soils

- Geodetic Control
- Hazardous Sites
- Historic Sites
- Wells/Septic Sites
- Topography/Elevations
- Parks
- Water Lines
- Sewer Lines

These are permanently maintained map features. Additional features may be displayed or plotted as maps from attribute data values and reference map features. Examples of these are maps of fires, crimes, or health cases plotted from files of these activities with symbols plotted at the locations of incidents.

Function or Application Data Sets

The function or application data are maintained and used by the individual application programs. They are generally data whose use is limited to the individual application. The incidents or entries are related to a specific geographic location through an address or other geographic identifier. In some cases, the attribute data will be entered and updated through MPLIS procedures, while others will be maintained by other systems. Mechanisms are provided for those that are maintained by other systems to move data to be used with the GIS mapping and analysis capabilities or for geocoding and geographic processing. These data are identified here to clarify the extent of land records processing.

The application data component can also be subdivided into data sets, including at least 12 parcel- or address-related sets listed below:

- Recorder Indexes
- Crime Incidents
- Hazardous Material Inventory
- Rezoning Cases
- Subdivision Cases
- Emergency Responses
- Well/Septic Permits
- Building Permit Characteristics
- Emergency Management Data
- Voter Registration
- Health Case Characteristics
- Special District Inventories

Application data may also include non-parcel-related sets such as:

- Traffic and Transportation Characteristics
- Highway Inventory
- Traffic Count/Volumes
- Facilities Inventory
- Parks Inventory
- Historic Sites Inventory
- Traffic Accident Characteristics
- Special Management Areas (e.g., well-head protection zone)

DATA STANDARDIZATION

An important aspect of the MPLIS data base is standardization of codes, nomenclature, and definitions within the components and their elements. If data are to be shared among the various functions in the jurisdiction, it is necessary to establish a set of standard coding schemes, data names, naming conventions, and definitions for each data element. The definitions should describe the contents of the element, the characteristics of the data representation, and any coding schemes used to record the data. The establishment of standards also requires that procedures be established to inform users of the standards and to monitor the data base to ensure continuous compliance with these standards.

There is also a need for standardization of certain data sets for shared use. Foremost among these are the street names and addresses of the GBF and parcel index. It is necessary to compile a comprehensive set of street names and addresses or address ranges for the jurisdiction. This standard set will be used by all address-related applications throughout the land records system.

A detailed discussion of standards, including the recently approved FIPS 173 (Spatial Data Transfer Standard (SDTS)), and metadata standards under development, can be found in chapter 20.

ORGANIZATIONAL DESIGN

Because an automated MPLIS typically serves multiple departments or units, the organizational structure or design for the MPLIS is very important. Several models are used for an automated MPLIS, ranging from creation of an MPLIS department, to a committee of MPLIS user organizations, to no organizational attention to MPLIS.

MPLIS resources are shared by several organizations and thus the resources must be allocated equitably. Therefore, organizational mechanisms must be developed to accommodate the multiple requirements. The focus on end users for operations requires that the users be involved actively in design and operation of the system. The MPLIS must operate within the overall organizational structure and administrative environment of the jurisdiction with minimal adverse impact. It should not contribute to an unnecessary additional layer of overhead.

Jurisdiction-wide coordination among participating departments can be served well through the establishment of an MPLIS user coordinating committee. The committee may establish policy or may be advisory only. It should establish or advise on priorities for system development and operation. It should be comprised of representatives, preferably at executive or management levels, of each of the participating departments. It should serve as a forum for communication between and among the participants. A separate technical committee may also be established to deal with and advise on specific system and data technical issues.

The actual development and implementation activities should be performed by system experts. For large organizations, a core group can be established within the Information Services, or equivalent, department or by specific assignments to persons in the department. For smaller organizations, these activities may need to be covered by cooperating user departments. Persons will also be assigned to MPLIS development and operation activities within each of the participating organizations as discussed elsewhere.

In many cases, there will be needs for skills beyond those available in the jurisdiction to perform development tasks using the RDBMS, GIS, or other specialized software and perhaps for the communications system. It may thus be necessary to arrange special training or hire consultants to augment current staff with persons with necessary skills. A carefully planned training program should be a significant aspect of MPLIS implementation. The training program should address not only initial startup, but long-term replacement and upgrade training. Where practical, internal training capacity should be developed to continue the training of future replacement personnel.

MPLIS AUTOMATION PERSONNEL ISSUES

To ensure qualified staff on a continuing basis, it may be necessary to establish new positions, job titles, and/or career tracks. Some new specialties may be necessary in the GIS, CAMA, communications, and other areas. It may thus be necessary to work with the personnel department to define appropriate position descriptions and establish equitable and competitive salary ranges.

The workload and personnel requirements for MPLIS development must be recognized. Additional resources must be assigned to the development effort. It cannot be expected that existing staff can continue with current assignments while also designing, developing, and implementing a new system of the magnitude of the MPLIS.

In some cases it may be appropriate to contract for specialized skills either on a temporary basis until permanent staff can be trained or on a long-term basis. In general, it is advisable to have permanent employees in most responsible positions, though they may be augmented by contractors during the development phases.

The user departments must recognize the need for staffing and training if they are to achieve maximum benefit from the MPLIS. In some cases one or more persons will be assigned full or a major portion of their time to MPLIS activities. Others will be trained to operate applications within the department.

There are several major roles played by the organizations participating in an MPLIS. Each organization may play one or more of these roles. The roles include systems manager, data base administrator, systems application development, or operator and user. These functions can be satisfied by a core MPLIS staff. A discussion of specific personnel positions and duties can be found in Chapter 8. In addition to these operational requirements, coordination of the interests and activities of the MPLIS will require a coordinating mechanism such as a committee or coordinator.

Systems Management - acquisition and maintenance of the hardware and software system. This role is the traditional data processing or information services department role. Some of the responsibilities include design, specification and acquisition of hardware devices, allocation of system resources to all functions and users, day-to-day operations and maintenance of hardware devices, liaison with system vendors, backup of data and software, system security, upgrade and replacement of components, management of communications system, maintenance of communications system, maintenance of all system documentation, and establishment and enforcement of system standards.

Data Base Administration - responsible for integrity of the MPLIS data base including logical data base design, physical data base design, definition of data base schema/structure, maintenance of data base directory, establishment of data quality and definition standards, monitoring and enforcement of data standards, operation of quality control procedures, and consulting with users on data base contents and usage. This role may be in information services or a data maintenance organization.

Systems Application Development - This is the technical role in which the modules and applications of the MPLIS are designed, developed, and maintained. It is generally a role for skilled programmers, though with modern software tools, non-programmer users may develop some applications themselves. The development activities must occur in accordance with the standards and designs of the system management. Included in systems development are: functional design, physical design, application programming, testing, documentation, user training, and maintenance.

Operations and Use - Numerous units and persons throughout the organization will operate MPLIS devices and programs and use the system for their various functions. In most cases these will be persons in land related departments who will use the system as part of and in support of functional activities of the department. These persons will perform several functions with the system, including entry, edit and verification of data; retrieval of data; generation of displays and reports; manipulation, combination, and calculation of data; and analyses of data.

INDUSTRY STANDARDS

A major change has taken place in the information technology industry in recent years that is evolving away from specific proprietary software products for each processor. Industry standards have emerged to provide greater compatibility between the separate lines of a vendor's processors and across the processors of various vendors. While the industry standards have not yet reached maturity and there are generally minor differences between the software of individual vendors, the trend is well underway and products are becoming more standardized. (See Chapter 20 for a detailed discussion of GIS/LIS standards.)

Use of industry standard products allows greater freedom in incorporating products of multiple vendors in a single configuration. It provides the opportunity to move programs from one processor to another. It facilitates accessing the programs of one processor from another or from a workstation in a network. It also minimizes the level of training and support required.

Open system architecture based on use of industry standards encompasses several important areas of required capability including:

Open System Interconnect (OSI) Model - a seven layer model defining a set of standard protocols for network communications. As yet standards have been established for only the physical network communications, layers 1-3.

Transmission Control Protocol/Internet Protocol (TCP/IP) - a suite of network communication protocols that corresponds to the lower 4 layers of the OSI defined by the Department of Defense and adopted by most major computer vendors.

Network File System (NFS or RFS) - a set of protocols for distributing file systems over a network of computers.

Structured Query Language (SQL) - a standard query interface to a relational data base management system.

X Windows - a standard multiple window interface made up of 3 components: a communications protocol, application development tool kit, and window manager. The Open Software Foundation (OSF) MOTIF has been adopted by several vendors as a window manager.

The use of these and other open system architecture industry standards in specifications for hardware and software will generally facilitate the integration of components within an automated MPLIS and between the MPLIS and other information systems of the organization.

KEY AUTOMATION ISSUES

Several information processing issues are of particular interest in automation of an MPLIS. Among these are:

Use of a DBMS versus application programs and files,

Differences between tabular and graphic (map) data,

Centralized versus distributed system configuration and organizational responsibilities, and

Implementation of major development projects versus evolutionary development.

USE OF A DBMS VERSUS APPLICATION PROGRAMS & FILES

A data base approach involves general management of a set of data independent of individual application programs with standard query, retrieval, report generation capabilities, and access provided to application programs from the common data base. The data are stored in the data base in accordance with a definition provided by the system manager. Changes in the data may be accommodated in most systems without major reprogramming. Reporting is performed by standard report generation functions that allow the user to specify content and format of the reports. Various DBMS software systems may be acquired commercially from numerous vendors for all types of computer systems from large mainframes to mini to micro or personal computers.

In the application program approach, a specific program or set of programs is developed for each application. These programs perform all functions, including data management and report production. The data files are directly related to the programs and may be imbedded in the application procedure. Changes in a data file will require changes in the application programs and often, after numerous changes have been made, the programs cannot accommodate further change without serious degradation. Any changes in retrieval or report production also require changes in the programs in this approach. The approach often involves redundant data storage among various applications.

The latter application program approach is often the most common in current use while the former data base approach is gaining rapid acceptance. To satisfy the requirements of the basic concepts of MPLIS, including sharing of data particularly, the data base approach is far more effective.

DIFFERENCES BETWEEN TABULAR AND GRAPHIC (MAP) DATA

Tabular data have been the most common, and in many cases only, form for recording land information. Tabular data are recorded as alphanumeric characters. Tabular data may represent sets of numbers, names, and other alpha words or codes comprised of numbers and/or letters. Tabular data require minimal storage capacity and may be processed to exploit the meaning of the numbers or text. Tabular data are used to record the identification and characteristics of land units or phenomena at geographic or land locations.

Graphic data are quite different. Graphic data describe the image of a map or other graphics entity. In vector form, graphic data are stored as X and Y coordinates for points on the beginning and end of lines. X and Y coordinates for points along a curve may be stored or the geometric definition of a curve may be recorded. Graphic data can also be stored in raster form as a combination of grid matrix or picture elements (pixels).

Graphic data are managed by a GIS to display and generate maps. In general, a much higher volume of data is required to define graphics images or maps than is required for tabular processes.

CENTRALIZED VERSUS DISTRIBUTED SYSTEM CONFIGURATION AND ORGANIZATIONAL RESPONSIBILITIES

The information system industry is undergoing a transition from centralized mainframe-based configurations to distributed networks. The distribution is taking many forms from numerous independent PCs to sophisticated client-server networks. The latter may incorporate multiple processors, including mainframe computers, PCs, workstations, and server devices. The servers may manage the data base and/or provide processing capabilities.

The data base may also take a central or distributed form. Even in a distributed network, the data base may be managed in a centralized manner or parts of the data may be distributed on multiple devices throughout the network.

The central versus distributed paradigm extends also to the MPLIS organization. A central department or group may operate the MPLIS, providing the data services to the various users, or the functions of entering, updating, managing, retrieving, processing, and distributing the land information may be distributed across multiple organizations. Like the data, a central organization can operate a central or distributed configuration and a distributed configuration is well suited to distribution of responsibilities.

IMPLEMENTATION OF MAJOR DEVELOPMENT PROJECTS VERSUS EVOLUTIONARY DEVELOPMENT

There are two basic approaches to the development of an MPLIS. In the first approach the MPLIS is developed and implemented through a specific project. That project typically includes design of the system and data base configuration, acquisition of necessary hardware and software components, system installation, development of programs and applications, development of the necessary data base, training of operators and users, and implementation. These tasks are all performed in accordance with a formal or informal project management plan to meet specific system requirements and criteria.

In the second approach, the MPLIS is implemented through an evolutionary process over time. In this case, an overall plan and design may be developed prior to implementation or the system may simply evolve in an expedient manner as various components are required. If a true MPLIS is to emerge, it will be necessary to prepare a design to ensure that the various, often very complex, components can be integrated into an overall system. This approach is generally taken in a situation where resources for full implementation are not available and their availability is uncertain. The approach must therefore take advantage of opportunities as they arise and allow reasonable time for training staff and learning new procedures.

SUMMARY

Automation of the MPLIS is a complex process, affected not only by the existing organization and its responsibilities, but by the ever changing technology of the computer related industry. The hardware and software components of the automated MPLIS must be integrated so as to satisfy the requirements of the organization and the system users. Knowledge of the latest technologies is essential if the automated MPLIS is to meet the expanding uses. And the organization of the data of the MPLIS will determine effectiveness of applications, present and future. Changes in the organizational structure may be necessary to parallel the development of the automated MPLIS.

In the next Chapter, discussion will concentrate on the key steps needed to implement the automation of the MPLIS.

REFERENCES AND ADDITIONAL READINGS
See Chapter 21.

23 GUIDELINES FOR AUTOMATION

Michael J. Kevany

AUTOMATION ROADMAP

This Chapter provides a "roadmap" for startup of an MPLIS automation project. It provides answers to key questions concerning MPLIS automation such as who are the players, where are we now, where do we want to go, and what do we do to get there? It begins with seven of the key players and the common questions each has regarding automation of an MPLIS and typical roles they play in MPLIS automation. Next is identification of some landmarks that will be found in the current environment. These include existing information systems and land information resources and alternative starting points or approaches based on these resources. These landmarks can be used to scope the project and to begin planning for implementation. Next is a discussion of organizational issues related to MPLIS automation. The chapter closes with a description of mileposts or task areas for MPLIS implementation.

KEY PLAYERS AND THEIR QUESTIONS

There are many potential participants in the automation of an MPLIS. These participants can include: city/county manager, information services director, register of deeds, assessor, planning director, public works director, and building inspector. Each has a different view of what is to be done and how it is to be accomplished. Some are managers with concerns about costs, resources, and efficiencies. Some are potential system users concerned about specific applications and how they will be incorporated into operations. Others are technical staff focusing on the details of automation. The functions and culture of the participating departments which they represent influence the perspective and concerns as well. This section begins with a series of questions that are commonly posed by various participants, followed by possible answers to those questions.

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CITY/COUNTY MANAGER

Why automate?

Because in some jurisdictions it has been shown to:

Improve staff productivity;
Allow current staff to provide more service;
Minimize or eliminate redundancies;
Improve operating effectiveness;
Improve the quality of decisions;
Allow better response to citizens; and
Minimize blunders and vulnerability to litigation.

How much will it cost?

For a small jurisdiction, as little as $25,000 to $100,000;
For a mid-sized jurisdiction $100,000 to $1 million, and
For a large jurisdiction, $500,000 to $1 million plus.

How do we automate?

Identify requirements,
Identify resources available and required,
Design the automated system,
Prepare an implementation plan, and
Carry out the implementation plan that includes many tasks identified in detail in the MPLIS Automation Project section of this Chapter.

Who does it?

A combination of Information Services, user departments (Assessor, Planning, etc.), consultant, system contractor, and possibly a mapping contractor.

How long will it take?

For a small jurisdiction or a minimal upgrade in a larger one, 2 to 6 months; for a mid-size jurisdiction, 3 months to 2 years; and for a large jurisdiction, multiple years for full implementation. A GIS alone can take 1 to 5 years.

INFORMATION SERVICES DIRECTOR

What is the scope of MPLIS automation?

Automation of an MPLIS can involve a single function or department, though the MPLIS should be automated on an organization-wide basis across numerous functions.

What are the hardware and software requirements?

The MPLIS may operate on existing platforms, though it will likely require an upgrade in hardware at a minimum. If the organization does not already have a data base management system (DBMS), one will probably be required. It may be necessary to acquire additional terminals, workstations, and software for the MPLIS. If it is necessary to acquire software, it may be necessary to acquire graphics workstations, digitizers, a plotter, and other components typically acquired as an integrated package.

What development will be required?

The necessary software may be acquired in part or entirely as an integrated package. Even if this is the case, it will likely require programming or application development to tailor the system to the specific requirements of the organization. This development effort will require from a few person-months to several person-years and/or contracts with a consultant, depending on the extent of the MPLIS and the size of the organization.

What is the relationship to our existing systems?

The automated MPLIS will likely replace at least some of the current systems. Existing software may be replaced with the MPLIS operating on existing hardware or the hardware also may be replaced. It may be necessary to develop a communications network to link workstations and PCs and to acquire file or data base servers for the network.

What special skills or services are required?

Expertise in the automation of land records will be necessary in any large organization. There are many peculiarities to the automation of land records that require special experience. A DBMS will require persons with adequate skills to design and specify the data structure and to develop inquiry and report applications. Implementation of a GIS will require GIS expertise, particularly in the areas of GIS graphics software, GIS applications design and development, and digital mapping.

REGISTER OF DEEDS

Will we have to assign PINs to deeds?

Yes, some form of parcel identifier number will be required so all recorded instruments can be related to the correct parcel.

Who will assign the PIN?

A specific person or unit may be assigned or created in the registry, assessor, planning, or other office to assign PINs. There will be a requirement that they be assigned quickly so as to have minimum impact on the recording process.

How will the PIN be assigned?

In many cases, the PIN will be added to paper maps before automation begins. It is also possible to use a module of the automated MPLIS that will compute and record the PIN.

Will we automate my indexes?

Yes, through the registry module and terminals in your office.

Will the public have access to the automated system?

Yes, they should, eventually, through public access terminals in your office and possibly through dial-in services.

TAX ASSESSOR

Will automation support my CAMA (computer assisted mass appraisal system) or allow me to develop one?

Yes, the automated system will capture, organize, and store data that can be fed to the CAMA. In fact, the CAMA will likely be a module of the automated MPLIS itself.

Who will control the automated MPLIS?

An MPLIS manager who will be assigned in one participating department. The manager will probably be in the

Information Services Department, though the position may be in any of the key user departments or a special office may be created.

Will automation require a change in my definition of parcels?

Automation won't, but development of an MPLIS may require a change to accommodate the needs of other departments. For example, more accurate mapping/COGO, that frequently is a part of land records modernization, may reveal gores and gaps in parcels, which may make some aspects of your job more difficult until these problems are resolved. Automation, on the other hand, may allow individual users to define parcels as they require by assigning identifiers, status codes, and other techniques.

Will automation impact my requirement for a December 31 inventory of parcel data?

No, an automated system can record dates and select data by any date so it will be possible to create the December 31 inventory. It may also be efficient to generate a copy of the data base as of December 31 as an historical record.

What will happen to my existing automated parcel file?

It can be linked into the MPLIS or replaced by an improved data base through MPLIS automation.

PLANNING DIRECTOR

Will I get access to data of the other departments?

Yes, through terminals or workstations in your office, assuming such use is authorized. Such access will allow you to determine the status of development "in-the-pipeline" at each of the required approval points.

Can I generate land use data from the automated MPLIS data?

You may be able to generate land use data through combinations of data recorded by multiple departments and related to specific parcels.

Can I aggregate data by census tract or planning area?

Yes, automation will allow geocoding of data by address to geographic areas such as census tracts and planning areas for aggregation.

Will I be able to perform spatial analysis?

Yes, an MPLIS will support extensive spatial analyses capability.

PUBLIC WORKS DIRECTOR

What will an automated MPLIS do for me?

It will provide direct and easy access to parcel and rights-of-way data and improved maps.

Can I use the MPLIS for my stormwater management program?

Yes, if a GIS is included, it will provide numerous capabilities including mapping, calculation of impervious areas, and data preparation for model input for stormwater management.

Can I use it for maintenance management?

The MPLIS can manage data about facilities, especially if a GIS is acquired. It can link with maintenance management models for data retrieval and provide organization in preparation for input to models. It can also provide the platform on which models can be built. With appropriate software, it can do "dynamic segmentation," maintaining information about different conditions and management on subsections of networks such as roads, pipelines, or cables.

Will I be able to link my MPLIS with my AM/FM (automated mapping/facilities management system)?

Yes, this capability will be possible, allowing you to link parcel and polygon data in the MPLIS with network data in your AM/FM system.

BUILDING INSPECTIONS DIRECTOR

What will happen to my current permit tracking system?

It may continue to operate independently or it may be augmented by or incorporated into the MPLIS, or a new permit tracking application may be developed within the MPLIS. The decision will depend on your interests, permit requirements, the capability and efficiency of the current system, and the resources available.

Can I use it to issue permits?

An application that will provide support for permit review and issuing can be developed with the MPLIS capabilities. Development of such an application will provide access to other county data from the permit procedures and will make permit data more readily available to other county departments.

LANDMARKS

EXISTING INFORMATION SYSTEMS, LAND INFORMATION RESOURCES, AND STARTING POINTS FOR AUTOMATION

A local government contemplating automation of an MPLIS today will likely fall into one of the four categories illustrated in Figure 23-1. In the first and simplest case, there may be *no current automation* in the organization. While no automation in local government is relatively rare, it may actually be because automation services are provided by contract or otherwise through another organization. In this case, the organization has the benefit of starting fresh and may pursue any of several options available, such as the microcomputer, mainframe, or network approach, with little or no constraint.

The second and third situations are an *existing limited or extensive mainframe or mini computer host-based system*. The limited system has few specific applications and possibly no MPLIS application. In the extensive system, many users are supported through numerous applications. In the case of a limited host system, it may be necessary to upgrade the existing configuration to accommodate MPLIS automation or to replace the processor or mass storage with a more powerful version. It will also be necessary to develop some or all MPLIS applications.

Similar options are available where extensive automation already exists. The current system may require upgrade or enhancement to accommodate MPLIS automation or it may be necessary to replace the current processor(s). These options, however, may be less likely where extensive automation already exists. In fact, an extensive automation environment is likely to include automation of some or many MPLIS applications already. So, additional capacity needs may be limited to a few applications or integration of existing applications. The most likely approach in this case will probably be the integration of MPLIS applications into efficient modules and into an overall MPLIS to facilitate sharing of data

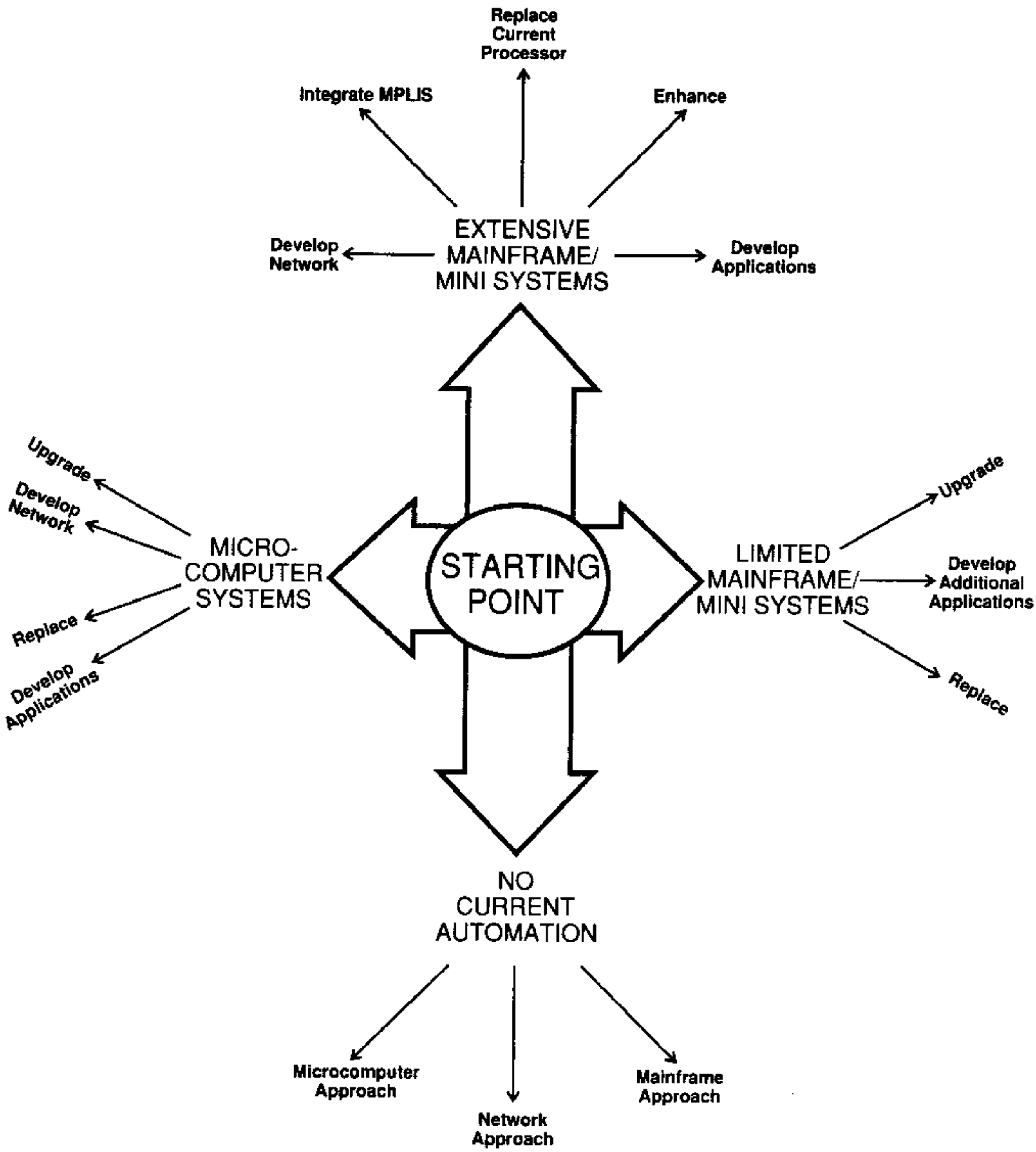

Figure 23-1: Starting Points for Automation

and resources. The addition of GIS capability and/or RDBMS are typically the mechanisms used to integrate existing functions.

Where automation exists, the key issue will be the extent of MPLIS or MPLIS-related applications. Where applications do exist, they should be evaluated to determine if they are adequate or obsolete and whether they can be integrated into a true MPLIS or whether they are too unique for practical integration. An evaluation should be made to determine if the most effective action is replacement of existing capabilities with an integrated MPLIS.

In the fourth category are smaller jurisdictions where the *starting point may be existing microcomputer system(s).* In this case, a limited MPLIS may be developed on the existing microcomputer using a DBMS, spreadsheet and application programs, or acquired MPLIS package(s). Automation of the MPLIS may, however, exceed the capacity of an existing microcomputer, requiring upgrade or addition of microcomputers. To accommodate a full function MPLIS in a microcomputer environment, it may be necessary to interconnect multiple microcomputers in participating departments or offices through a communications network.

All possible combinations of alternatives facing an organization at the starting point of MPLIS automation are too numerous to discuss in detail in this guidebook. However, some of the more common alternatives are discussed in the following section.

Microcomputer Approach

For small jurisdictions or departments within a large organization, one or more microcomputers may be adequate for MPLIS automation. Typically, microcomputer systems are developed using a commercial DBMS and/or spreadsheet package. These will serve to easily store, manage, and report the data of the MPLIS. In some cases, it may be necessary or desirable to augment these with specific programs developed in a programming language or software package. There are also microcomputer-based packages that can be acquired for some modules or components of the MPLIS. These preprogrammed, off-the-shelf packages are generally easy to implement, requiring minimum development effort, though they will be standardized and thus may require adaptation in a local environment to operate efficiently. More powerful "workstations" can also be operated as stand-alone platforms for the needs of a small jurisdiction or single department.

Mainframe/Mini Host Approach

The most common current information system configuration in local government is host processor-based, in which a mainframe or mini computer provides most or all processing and data management capability for the system. The users access the system through terminals that are wired to the host by cable or that access the host through modem over a telecommunications network. This configuration can support a wide range of alternative software approaches from individual COBOL or other programs for each module and application through hybrid variations to complete operation with a DBMS. For example, a simple application may use the reporting and query capability of the DBMS, while more complex applications or those requiring special calculations may be developed in a programming language and may still access the DBMS for necessary data.

The host approach has the potential to support many users simultaneously and to provide a wide range of MPLIS modules through an integrated set of components.

Distributed Network Approach

The third basic approach to the MPLIS configuration is a distributed network in which multiple individual processors are interconnected through a communications network. This allows sharing of data and system resources and access to data and programs from multiple locations throughout an organization. The network may be composed of mainframe, mini, server, microcomputer, and workstation processors, as well as many types of printers, terminals, plotters, and other peripheral devices. The MPLIS programs may reside on any processor in the network and the data base or parts of it may reside on any mass storage device in the network.

Upgrade of Existing System

The existing processor(s) may have inadequate processing and/or storage capacity to support additional or improved MPLIS application modules, particularly if geographic and GIS software are added. It may therefore be necessary to upgrade the capacity. The upgrade may be an addition or swap of boards in an existing computer to add necessary speed or processing power; addition of mass storage capacity; replacement of existing processor with a new, more powerful one; or addition of a processor to a cluster or network. The upgrade may be made within the same vendor family of devices or a more powerful configuration may be acquired.

ORGANIZATIONAL ISSUES RELATED TO MPLIS AUTOMATION

As a multi-user operation, the MPLIS must be supported by a special organizational structure. Within each user department, there will be organizational components to manage the system within the department, enter data, and operate the system. There may be from three to a dozen or more such groups. The groups may be organized differently within each department. In some cases, there may be a specific unit, while in others there may be loosely coordinated individuals performing the various functions.

There will also be a need for a core staff. This staff may range from one person performing MPLIS functions on a part time basis with other responsibilities to several persons working full time in a specifically designated MPLIS organization. This unit will oversee MPLIS operations, may provide support services to user departments, will manage the automated MPLIS system, and will coordinate the activities of users. The unit may include a system manager, data base administrator, systems analysts, and programmers to develop and maintain the automated system.

The next two sections of the Chapter discuss the responsibilities of the personnel within the organization that will be involved in MPLIS automation. Across all participating departments, there will be a need for coordination. This may be performed by a committee of MPLIS users and the core staff. The committee will direct or advise the core staff. It may address issues such as system policy, data base content, maintenance responsibilities, and application and data development priorities. It may coordinate the development, data entry, and use by the participants.

ORGANIZATIONAL ROLES

There are a number of organizational roles that must be filled if the automated MPLIS is to be successful. Listed below are many of the functions and offices that typically are part of the

MPLIS, along with examples of their organizational roles. Note that these are generic responsibilities. The actual officials or offices that carry out the activities can vary from one jurisdiction to another.

City/County Manager - Overall management; authorize project and acquisitions; allocate resources; assign responsibilities; obtain funding; inform elected officials of progress; establish MPLIS implementation organization.

Information Services Manager - Manage system design and development; acquire hardware and software; coordinate development and implementation with users; allocate and assign technical systems staff; manage maintenance of system; manage system and data base.

Register of Deeds - Source of parcel data; acquire or develop and operate major module for registry; may be user of document management component; control requirement for parcel identifier; must implement new parcel identifier based index.

Assessor - Establish department requirements; may be sponsor of project; provide existing automated files and tax maps; update parcel data; define parcel number.

Planning - Often a major MPLIS supporter, often takes lead to identify funding or justification for funding, coordinates MPLIS activities, develops internal capabilities, and participates in application and data base development.

Public Works - Develops internal capabilities, provides funding or justification, participates in application and data base development.

Building Inspections - Develops internal capabilities, provides funding or justification, participates in application and data base development.

Utilities - Develops internal capabilities, provides funding or justification, participates in application and data base development; develops facilities management module.

Police - Develops internal capabilities, provides funding or justification, participates in application and data base development; maintains geofile of addresses and beats; may integrate MPLIS with E911.

Fire - Develops internal capabilities, provides funding or justification, and participates in application and data base development; may integrate MPLIS with E911.

Parks - Develops internal capabilities, provides funding or justification, and participates in application and data base development.

Inter-Organization Structures

MPLIS Coordinating Committee (Chair - executive/manager; members - department heads of key departments) - set policies, priorities, annual budget; establish standards; decide on issues raised by Technical Committee and core staff.

MPLIS Technical Committee (Technical representatives of user departments) - define/recommend standards; coordinate technical activities; coordinate joint development projects; address specific technical issues raised by core staff or users.

Core Staff (Group within Information Systems Department focussed specifically on MPLIS) - provide all system management, data base administration, development, support, and maintenance for automated MPLIS; staffed as described below; managed as line unit within Information Systems Department.

User Staff (Assigned within MPLIS user departments) - specialize in MPLIS activities; perform user department functions; maintain user department resources; provide consulting to department users; may design and develop department applications.

WHAT PERSONNEL SKILLS ARE REQUIRED?

Several positions or personnel functions will be required. Depending on the scope of the MPLIS, responsibility for multiple functions may be assigned to a single person or individual functions may be assigned to multiple persons. The positions typically required include the following:

Project Leader or Manager - manages and controls the automation project resources; assigns responsibilities for individual tasks; monitors progress; assures completion of all tasks; assures quality of all work and products; reports progress to management.

MPLIS Expert - Design the automated LIS system; design LIS applications; advise on system acquisition, development, and implementation.

System Administrator or Manager - Manage the automated LIS hardware and software components; authorize access to the system; manage system maintenance activities; resolve problems with system operation; install system upgrades; monitor system utilization; advise and assist system users.

Data Base Administrator - Design automated data base; produce data base definition specifications; establish and enforce quality standards; authorize access to data base components; assign and monitor update and maintenance responsibilities.

Systems Analyst - Design and develop automated LIS and individual applications; document system and applications; train system users; maintain and update programs.

Programmer - Produce computer programs designed by the analyst; document programs; train users in system operation.

Functional Experts/Users - Provide information on LIS automation requirements and design parameters; accept design specifications; test system applications; learn LIS and application operations.

A more detailed discussion of MPLIS personnel can be found on pages 29 and 30 of Chapter 16 of this Guidebook.

MILEPOSTS OR TASK AREAS OF THE MPLIS AUTOMATION PROJECT

OVERVIEW

Development and implementation of an automated MPLIS may be a relatively simple or very complex and costly process, depending on the size of the jurisdiction, the extent of automation, and the current automation situation. Ideally, the automated system should be designed as a comprehensive support to most or all aspects of an MPLIS. As an expedient measure, individual modules of an MPLIS might be automated, but even in this case they should be designed with the overall MPLIS in mind.

The development and implementation of an automated system involves numerous tasks that might be grouped into 12 basic task areas. The complexity and effort of the tasks is dependent on the individual project, but all 12 areas should be addressed at some level, even in relatively small projects. The 12 basic areas are:

1	Perform Requirements Analysis
2	Perform Conceptual Design and Feasibility Study
3	Prepare Strategic & Implementation Plan
4	Establish Organization & Train Staff
5	Design System
6	Design Data Base
7	Acquire Automated System Components
8	Install and Implement System
9	Develop Data Base
10	Design & Develop Application Programs & Operating Procedures
11	Conduct Pilot Project(s)
12	Conduct Automated Operations & Maintenance

Several of these areas will require technical expertise in automation and/or the subject matter of the applications to be developed. In some cases it may be necessary to acquire expertise through Federal or state government technical assistance programs, from consulting firms, from universities, or from other sources. An organization considering automation of an MPLIS should conduct an analysis and at least the conceptual design of the overall MPLIS automation before moving to implement any specific application. (It is not necessary to undertake these 12 areas in exactly the order outlined above). It will ensure that all parts of the automated MPLIS will be compatible. The basic concept of multiple use and other aspects of the MPLIS require this approach if automation is to be successful. (See Chapter 14 for another version of these general activity areas.)

The following is a discussion of the 12 areas involved in MPLIS automation.

(1) PERFORM REQUIREMENTS ANALYSIS

The first step in automation is typically to conduct a needs assessment to identify the requirements for information, processing, and products. The design and development of the automated system will be based on the needs identified. The data needs analysis must involve the potential users of the system to ensure that the needs identified represent the true requirements of the organization. (Chapter 16 includes a detailed discussion of assessing data and product needs, and the hardware and software requirements necessary to support these needs).

The needs analysis will consist of three subtasks: information collection, analysis, and documentation. The information collection subtask should include:

A review of current operations and resources;
Definition of business functions;
Compilation of an inventory of existing data, maps, and information used;
An inventory of automated files and systems in use or in development;
Identification of the sources for data and maps; and
Identification of problems with current operations.

The information collection task should also include information needed beyond the needs analysis, such as costs and resources allocated to current operations. It should include interviews with representatives of the organizations involved; completion of data, file, and map inventory forms as information collection instruments; and review of documentation of current conditions and plans. The information collected in this task should be documented and organized for use in subsequent tasks.

An analysis of the collected data should identify information acquired, processes performed, flow of data among positions, organizations and products, or actions taken. The analysis should be conducted to identify the data to be included in the automatedsystem, the processing capabilities required and the display, report, or map production requirements for the system.

These items must be documented in a form that will be useful in the subsequent decision and design phases. It might include data definitions, flow diagrams, report formats, and process descriptions. The extent and degree of formality of the documentation will be tailored to the complexity of the automation project being considered. The initial document should be reviewed with the participating organizations to verify accuracy and completeness. Following that review, the analysis can be finalized based on user comments received.

Checklist for Requirements Analysis

Identify participating organizations
Identify persons in each organization to be interviewed
Prepare data collection forms
Prepare interview questionnaires
Collect background information for each organization
Conduct interviews
Complete data collection forms
Collect supporting materials
Organize information collected
Produce data and map inventories
Identify business functions
Document current operations
Analyze information collected
Identify data needs, including integration and analysis needs
Identify processing capabilities needed
Identify products needed
Identify problems with current operations
Document needs identified
Review with participating organizations
Finalize needs analysis

(2) PERFORM CONCEPTUAL DESIGN AND FEASIBILITY STUDY

Prior to automation, some form of conceptual design and feasibility analysis should be conducted. A microcomputer acquisition may require only a very simple, informal analysis. A major automation project, on the other hand, may involve millions of dollars and require a very thorough feasibility analysis. Some local governments have specific requirements for an analysis and the form it must take prior to acquisition of an automated system. (Chapter 15 addresses the general topic of economic evaluation of an MPLIS system.)

Economic Feasibility

The feasibility analysis typically focuses on the economics of automation, though other issues such as technical and institutional feasibility should also be considered. The feasibility analysis will draw on information collected and the findings of the requirements analysis. One aspect of the feasibility analysis will be an estimate of the costs of current operations and a projection of these costs into the future 5-to-10 year life cycle of the automated system.

To estimate costs of continuing current manual tasks, data can be acquired and analyzed on the volumes of various activities and the time and resources involved . The scenario for performing the required function in an automated environment can be developed and the costs of that approach can be estimated for comparison. The first step in this will be conceptualization of one or more automated configurations. The conceptualization will use the findings of the Requirements Analysis as the basis for identification of the capabilities required of the automated system. In some cases the conceptualization will be an entirely new system or in others, an augmentation of an existing system or a system that will be linked to an existing system.

Using the data processing and output requirements identified, a conceptual system will be designed providing the necessary hardware devices, processing software, and data sets that satisfy the requirements. Alternative configurations may be conceptualized and evaluated if options are appropriate. The alternatives may involve centralized and distributed approaches or the extent of automation to be implemented.

The costs of the conceptualized configurations will then be estimated. The costs include:

acquisition of hardware devices,
acquisition of software,
acquisition of communications network,
application programming,
development of the data base,
automation of data,
preparation and implementation of the system,
maintenance of the hardware and software,
potential upgrades required during the life cycle,
staffing,
training, and
operation of the system over the system life cycle.

These costs should be estimated from the cost of similar systems being implemented. Ranges of costs will generally be appropriate since specific costs are not available at this stage. Since systems use will extend over multiple years, the value of the money and impacts of inflation should be included in the cost estimation. The costs should be documented in a format that will facilitate comparison of the costs of automation to those of the current approach.

It is important to perform the cost estimates accurately. Persons wishing to justify or reject a system have a temptation to over or understate the true conditions or use optimistic or pessimistic factors in generating estimates. The person(s) charged with conducting the feasibility analysis should be selected carefully to be objective, yet knowledgeable. The presentation of the results of the analysis should support estimates made to allow verification. In some cases it may be appropriate to bring in an "outside" objective party to conduct the feasibility analysis to obtain expertise and to enhance the credibility of the finding.

Another important aspect of the feasibility analysis is an investigation of benefits to be anticipated from automation. The benefits are typically divided into quantifiable and nonquantifiable categories. Quantifiable benefits are those for which specific values can be reliably calculated or estimated. These involve savings in personnel costs, acquisition of equipment and materials, contracting for services, or other areas. They are estimated on the basis of changes that will occur in shifting to automated operations.

Quantifiable benefits can be further divided into those that are a direct result of automation, e.g., a redundant map updating operation can be eliminated, and those that will come about indirectly, e.g., the results of errors that can be eliminated by improved availability of information. These indirect benefits are particularly difficult to quantify reliably.

Quantifiable benefits or cost savings may result from current costs that can be terminated with the availability of an automated system or from avoidance of costs that otherwise would be required if an automated system were not available.

The comparison of the estimated costs of continued current operations with those of the alternative automated approaches will indicate much of the direct quantifiable benefits or cost savings. These are probably the most reliably estimated benefits.

Quantifiable benefits may also be identified in a number of other areas. These include additional tax revenue that may be obtained by a more complete and accurate description of the properties, improvements in response times to engineers and developers, resulting in savings in the private sector, or the avoidance of blunders that result in litigation and other costs.

Non-quantifiable benefits should also be identified in the analysis. These are improvements in operations, the quality of service, or other aspects for which actual values are difficult or impossible to estimate reliably. Many non-quantifiable benefits can be obtained from automation of the MPLIS functions. Areas such as the speed with which information can be made available, the flexibility with which they can be organized and presented, and the integration of multiple sources are important opportunities for benefits from automation. (Examples include E911 systems and development scoping.)

Costs and benefits that have resulted from similar automation activities in other jurisdictions, if information on them can be acquired, may be used to provide data for estimation purposes and as comparisons to support the findings of the analysis. They should be used judiciously however, as conditions in different organizations can affect the results of automation dramatically.

Technical and Functional Feasibility

The automation alternatives should be reviewed and evaluated for their technical and institutional feasibility. Will they actually operate in this specific environment? Does the organization have the personnel and other resources necessary to function properly and achieve the benefits anticipated? Will the necessary data actually be available and can they be entered in a practical manner? Will the proposed users actually make use of the capabilities of the system as envisioned? Are the processing capabilities identified readily available in the market or can they be developed reasonably?

The results of the feasibility analysis should be documented in an appropriate manner that will facilitate the decision making process. This may mean summaries of findings and recommendations supported by more detailed information and analyses to allow verification.

Checklist for Feasibility Analysis

Formulate assumptions: inflation, interest rates, and other factors
Acquire data from the requirements analysis
Analyze current procedures and acquire or estimate costs at each stage
Summarize current cost estimates
Calculate costs of continuation of current practices over projected system life cycle
Analyze data needs
Define conceptual data base requirements
Analyze processing needs
Define software processing capabilities required
Define conceptual software components
Analyze volumes, processing capabilities, and user locations
Define hardware requirements
Design conceptual hardware configuration
Evaluate alternative configurations
Select configuration for further evaluation
Estimate configuration costs for hardware, software, communications, development, and maintenance
Estimate staffing and support requirements
Estimate personnel and operations costs
Develop scenarios of automated operations in each process
Compare current and automated operations
Identify and estimate quantifiable benefits from automation
Identify and describe non-quantifiable benefits
Review and evaluate technical feasibility of automated alternative
Review and evaluate organizational impacts of automation
Document various findings
Analyze and evaluate findings
Develop recommendations on feasibility of automation
Present findings and recommendations to management/executive staff
Decide on MPLIS automation

(3) PREPARE STRATEGIC & IMPLEMENTATION PLAN

The development and use of an MPLIS will typically be a major endeavor lasting multiple years and costing hundreds of thousands or millions of dollars. It will also be a very complex endeavor involving multiple departments, numerous skills, system vendors, consultants, software vendors, management, and others. To manage and conduct the design, development, and implementation of a project of this magnitude successfully, it will be necessary to have a carefully prepared plan. Even in a relatively simple MPLIS automation project, a plan will be useful. In a major project it may be necessary to prepare both a strategic plan for executive and management level control and an implementation plan for day to day project management. The strategic plan will address policy, major phasing, funding strategies, and general resource commitments.

The project management plan will also address:

task definitions
resource allocations
responsibilities
milestones and products
schedule, and
management controls and procedures.

The implementation plan will identify and describe each task in the system implementation process. Task areas to be addressed include those identified in this chapter. Within each of these areas several tasks may be identified. For example, the system design may be divided into each application area with tasks addressing:

functional analysis,
functional design,
detailed design,
data base design,
documentation,
user review, and
final design.

In addition to the task descriptions, the plan will identify resources to be allocated for each task, including staff, consultant, contract dollars, and acquisition dollars.

The responsibility for each task will be defined, including management responsibility and responsibility for performing the task. To monitor and control progress, the plan will identify measurable milestones and products for each task in the project. A schedule will be established for the project, identifying the time increments for each of the milestones. Ideally the schedule should include planned and actual, beginning and end, dates for each task. The plan will also describe the management controls and procedures to be employed to monitor, verify, direct, and report progress throughout the project. A part of the management should be continual monitoring of actual experience relative to the plan and to modify and update the plan to reflect the changing conditions.

Checklist for Strategic & Implementation Planning

Identify project tasks
Define project tasks
Allocate resources to tasks
Assign responsibilities for tasks
Define task milestones and products
Establish project schedule
Establish management controls and procedures
Prepare project implementation plan
Monitor project progress
Report project status
Modify plan as necessary

(4) ESTABLISH ORGANIZATION AND TRAIN STAFF

The organization to develop, implement, maintain, and operate the automated MPLIS must be established. The organization structure will include core staff assigned specifically to MPLIS automation, MPLIS implementation project management, user coordination and technical committees, and MPLIS elements in user departments. All necessary staff positions will be identified, defined, and authorized. Personnel will be selected or recruited and assigned to the positions. The managerial and committee structure will be established and managers and committee representatives will be assigned.

Staffing an automated MPLIS may follow several patterns and must be tailored to the specific environment. Staffing may be provided through existing organizations that perform various automation functions or a new MPLIS automation unit may be established to develop and operate the MPLIS. The expertise required for the staff will involve several areas, including computer systems, programming, data base management, information processing, automated mapping, and others. In general, there will be needs for the staffing capabilities outlined earlier in this Chapter. Each of these capabilities may be provided by one or several persons depending on the size of the organization and the scope of the MPLIS automation.

In addition to core automation positions, the automated MPLIS system will require staffing for data entry and for retrieval and production of reports and maps. These positions may be in a core organization or, more likely, will be in operating units that use the

MPLIS system. They may be persons dedicated to entry or retrieval or persons who use the system as a part of another basic assignment such as permit processing, assessment, or land use planning.

Staffing of the MPLIS automated system will also require a comprehensive training program. It will be necessary to prepare a training plan that identifies the training required, specifies training sessions, and identifies participants and responsibilities for the training. Training will be necessary in automation concepts and the capabilities of the systems installed for managers and users of the automated system.

Technical training in the system and software will be necessary for the analysts and programmers who will produce application programs and maintain the system. Those who will operate the system directly must be trained in the operation of the hardware devices and programs that they will use. Extensive training in all aspects of the system and its management may be necessary for the system and data base managers, especially if existing county personnel are to be appointed who do not have experience with this technology or the specific systems involved.

Much of the training may be provided by the vendors of the systems being used. There may be a need to arrange for additional training from other sources, especially in the area of concepts and use of the systems. This training may be provided by other firms, universities, or professional organizations. Remember also that training is not only necessary when the systemis implemented, but will continue periodically over the entire life cycle of the MPLIS.

Checklist for Staffing and Training

- Analyze staff requirements
- Identify staff positions
- Define positions
- Assign or hire staff
- Analyze training requirements
- Identify training sources
- Prepare training plan
- Prepare or acquire training components
- Conduct training
- Monitor positions and update as necessary

(5) DESIGN SYSTEM

If a positive decision is made regarding MPLIS automation, the design of the system will begin. The design will use the concepts for the configuration selected from the feasibility study and refine it significantly. For a large, complex system a two stage approach of conceptual and detailed design will take place. If an existing computer system is to be used, the design will be tailored directly to that system. If a new system is to be acquired, the initial design should be at a functional level to allow preparation of specifications and an RFP that will not rule out reasonable offers. The system design will require technical expertise in computer systems and these experts will be familiar with various methodologies such as CASE tools that are used in the computer industry for the design of automated systems. The description here is purposely general to provide the non-computer expert manager or participant with an overview of the work involved.

In this task, the MPLIS hardware, software, and communications system will be designed in detail. The design will require an information collection effort similar to that of the feasibility analysis. Updated and more detailed information will be required for the design. The information needed will include the specific definitions of data files and items, volumes of data to be stored and processed, detailed descriptions of the rules to be employed in processing operations, locations of users, processing capacities, specific flows of information, and other information necessary to specify system capacities and capabilities.

The analysis of the design data will be used to define the specific requirements for all aspects of the system. The functional requirements for hardware devices and their capacities and characteristics will be specified, as will the functional requirements for software processing, management capabilities, and network communications.

Based on the requirements identified, the overall system configuration architecture will be designed. The design will define all components and their relationships, including the locations for storage and management of data and the communications network for providing access to all MPLIS users.

The functional requirements will the be used to define the detailed specifications for each of the components of the automated

MPLIS. The functions, capacities, and other characteristics of each of the hardware devices will be specified. The software processing functions will also be defined, including data base management, access and query, reporting, mapping and graphics, spatial analysis, access controls, and other MPLIS capabilities. The communications network will be designed to provide a satisfactory level of access and linkage between and among all nodes in the MPLIS configuration.

The design will be documented in accordance with the standards of the method employed for the system design. The documentation should be in adequate detail to support acquisition of components and implementation of the system and to provide the basis for application design and development. Therefore, it should include sufficient detail to support decisions regarding data custodianship, access and security, and cost allocation.

Checklist for System Design

- Gather detailed information on existing systems, prior studies, specific data and other definitions, flows, and product descriptions
- Analyze information collected
- Define hardware system requirements
- Define software requirements
- Define communications requirements
- Design overall configuration architecture
- Specify hardware components
- Specify software components
- Specify communications components
- Document system specifications

(6) DESIGN DATA BASE

Various methodologies are available for the design of an MPLIS data base. The design is based on the requirements of each of the user functional areas. The methods therefore begin with a requirements analysis. Again, various tools known to data processing managers, such as "structured systems analysis" or CASE may be used in data base design.

The design must identify the data contents in terms of individual data items, the definitions of each item, the characteristics of each item, any coding schemes or representations to be employed, quality standards, and specifications. For the graphics data uniquely identifiable in a GIS, the source and representation, scale, positional accuracy and spatial intelligence, such as topological relationships, symbology, and annotation characteristics, must also be defined.

The overall data base design is divided into two phases, logical and physical design. The logical design is more general and independent of specific software and data structures to be employed for implementation. The physical design is stated in terms of system specific definitions that can be directly coded into the software.

The data base design must identify sources for initial acquisition and for continual update and maintenance. It must also define procedures for capture, preparation, entry, and edit of each data element in the data base.

The design must specify the quality standards to be maintained in the system, including the meta data (data about data) to be recorded. The quality of data is important information for users to determine the reliability to be placed in the data. Quality may be stated in terms of source, lineage, entry methods, quality controls, and logical consistency. The quality characteristics should be recorded and maintained for all MPLIS data sets.

Checklist for Data Base Design

- Analyze data requirements
- Define data items
- Define data characteristics
- Define coding and representation schemes
- Define data quality standards and specifications
- Define scale and accuracy
- Define spatial intelligence or topology
- Define symbology and annotation
- Prepare logical design
- Review with users
- Finalize logical design
- Define system-specific data specifications
- Prepare physical design
- Define meta data structure

(7) ACQUIRE AUTOMATED SYSTEM COMPONENTS

System acquisition may take several forms. It involves both hardware and software, and may include a variety of services such as design, installation, application development, and data automation. This section deals with acquisition of hardware and software. The following are options that may be encountered, each of which will involve a somewhat different approach to acquisition. Various combinations of the hardware and software options may be used.

Acquisition of the system will be based on the design phase. The design will be converted into specifications for the acquisition. The specifications for the system should be described in terms of the functional requirements rather than the details of specific vendors and models to allow the widest offering of potential vendors.

In most local governments, acquisition of a system will require some form of competitive procurement involving a request for proposals (RFP) or bids, an evaluation of the proposals, and selection of the vendor and system to be acquired.

A thorough acquisition process can be expensive and time consuming. It will involve multiple jurisdiction personnel. It may include travel expenses for several persons to visit existing sites or conduct benchmark tests. The extent of the evaluation process should be related to the magnitude of the procurement and the risk of a mistake in the selection.

Acquisition will begin with an information gathering effort. For a period of time before actual procurement begins, those involved should take opportunities to acquire information on relevant systems. Attendance at conferences, especially those with system exhibits; visits to other organizations that have implemented similar systems; reviews of literature and other sources are all useful ways to gather information.

Since system acquisition is a very technical activity, it may be appropriate to retain a consultant to assist if local personnel do not have adequate breadth of expertise. The consultant can be helpful in preparing specifications, establishing and assisting in the review process, and negotiating a contract. The selection decision should always be made by the organization acquiring the system, even where outside advice is used. (Further discussion on the use of consultants can be found in Chapter 14.)

A next step is preparation of the RFP describing the functional specifications of the hardware and software to be acquired. The RFP should describe a format for proposals to facilitate evaluation. The RFP should also describe the evaluation process, selection criteria, and differentiate between mandatory and optional items. Options are those components that are needed, but which are not absolutely necessary for the basic functioning of the system. An evaluation team should be formed of appropriate representatives of the participating organizations. The team should include expertise in all aspects of the procurement, including hardware, software, communications, application needs, and any special aspects of the system and its use.

A list of potential vendors of the type required should be assembled from several sources. Among the sources are professional organizations that provide such lists, vendors that have made contact, other local governments that have made similar procurements, and advertisers or those listed in publications. Preliminary "requests for information" or "requests for qualifications" can be used as an initial screening process for potential vendors.

The RFP will be published and distributed to those on the vendor lists and others that request it. An adequate time should be left to prepare responses. The appropriate period will depend on the extent and complexity of the procurement, but should probably be a minimum of one month. A bidder's conference should be conducted for large procurements during the proposal period to allow an opportunity to clarify issues. In general, it is important to allow the greatest exchange of information with potential proposers, though unfortunately many procurement regulations seriously restrict the exchange in the interest of equity.

When the proposals are received, they should be accounted for and evaluated in accordance with an objective procedure. The evaluation team will be convened and instructed on the evaluation procedures. Each member will be provided a copy of each proposal to evaluate. The mandatory items should be verified first and any proposals with serious deficiencies should be rejected. The mandatory and optional items provided should be evaluated and scored in accordance with the procedures developed. In addition to the technical descriptions of the system offered, the qualifications and experience of the vendors should be evaluated. The system may require special expertise on the part of the vendor for its development. The firm certainly must be financially viable to remain in business throughout the life cycle of the system to provide necessary maintenance and support.

The scores of the various evaluators should be tabulated and a meeting may be conducted to discuss progress. If any offers are clearly not competitive, they should be dropped at this time. Next the references of the vendors should be checked carefully. A specific set of questions should be asked of the references and any problems or issues should be explored.

A part of the evaluation may be benchmark tests or site visits to operating sites or a combination of both. A benchmark test is a specific exercise of the system capabilities that is evaluated. A short list of a few especially well qualified offerings should be selected for benchmark testing or site visits. The test should be carefully constructed in advance and delivered to proposers remaining in contention. They should be given adequate time to prepare for the test, but the test should be structured to restrict special developments that blur the evaluation. The vendors may conduct the test at no charge or may require a fee. The buying organization must recognize that the vendors must make a reasonable return and therefore cannot be expected to perform extensive tests without charge. Funds should be budgeted to cover necessary costs including travel, and the test should be designed to be reasonable.

The test will require preparation of materials, data files, maps, or other items that will be provided to the vendors to be used in the test. It will also require specification of the test functions to be performed, products to be generated, and information to be recorded. The scenario of the test must also be specified along with the minimum configuration to be used.

The test is typically conducted at the vendor's location, though it may be conducted at the purchaser's or a third party site. Some or all members of the evaluation team will observe the test, guide its conduct, and record information on the results. Design of the test is a complex process and tailored to a specific acquisition. It should verify basic operations and test any special or questionable items of hardware or software. The ease of operation and timing of functions may also be evaluated. Each evaluator will record results of the test and the results will be tabulated.

Site visits may be conducted in place of or in addition to benchmark tests. The visits should be made to sites in which identical or similar systems are in operation. Sites of similar applications should also be selected. The site visits should be carefully planned to acquire a maximum of information with minimum impact on the site. A series of questions and demonstrations may be part of the site visit. The focus should be on the local operator and not the vendor and sufficient time should be available to discuss experience, capabilities, and problems with the system operator.

The vendors may also be called to an interview. In the interview, any problems with the proposal should be discussed, ambiguities should be clarified, and capabilities of the vendor should be explored. The interview should offer the proposers an opportunity to provide a summary of the proposal and vendor organization followed by a question and answer or discussion period. The evaluation team should prepare its questions in advance and the chairperson should conduct the interviews in an orderly manner. The information provided should be recorded and incorporated into the evaluation.

The results of these various activities should be summarized and provided to the evaluation team. The team should meet, discuss the findings, and arrive at a recommendation on the offer to be accepted. The team structure should be established to encourage consensus and minimize disagreement throughout the evaluation period.

A contract or contracts will be negotiated with the selected vendor(s). This may be an extensive process depending on the complexity of the system acquisition and the combinations of firms involved. In some cases it can take up to six months or more to define exactly what is to be procured and the terms and conditions of the acquisition including warranties and maintenance agreements.

Checklist for System Acquisition

- Prepare functional specifications
- Prepare RFP
- Prepare evaluation procedures and criteria
- Organize selection team
- Issue RFP
- Conduct prebid meeting
- Receive proposals
- Log and verify
- Evaluate and score proposals
- Select short list of offers
- Check references
- Conduct interviews
- Conduct benchmark tests
- Conduct site visits
- Make final selection
- Negotiate contract

(8) INSTALL AND IMPLEMENT SYSTEM

If the MPLIS is to be automated with a personal or micro computer, installation and implementation may be a relatively simple task. It will involve connecting the various devices, learning to operate the software, such as a data management system, loading necessary data, and beginning operation.

If a mainframe or distributed system is used, the process will be more complex. If an existing computer system is to be used, new software and/or programs may be installed on that system and additional terminals or other devices may be installed. If a new system is to be acquired, which will commonly be the case if a GIS component is to be automated, installation will involve a series of tasks that include site preparation, network installation, delivery, system installation, acceptance testing, initial operation (often in parallel with continuing manual operations), and phase-over to automated operations.

If a new computer system is to be installed, it may be necessary to prepare a site for its location. Site preparation includes constructing an appropriate room or facility, installing communications network, installing adequate power service, installing environmental controls to cool and maintain proper humidity, and in many cases security controls to limit access to the computer facility to authorized persons. The vendor of the system will at a minimum, provide necessary specifications such as power requirements and guidance for preparation of an adequate facility. The vendor may also provide all preparation and systems integration services.

The vendor will deliver the system devices to the site and install all components. The installation will include connecting the various devices to each other and to the network and generation of the operating software system on the processor(s). All modules of the software will be installed and test operations will be performed by the vendor to verify that all components are operational.

The county (or other MPLIS organization) itself should then begin operation of the system and conduct a series of tests prior to accepting the system and authorizing full payment. An initial set of actual county data should be entered and a series of typical operations should be conducted by county staff to further verify proper operation under actual conditions. This test should be included in the negotiations and in the contract as a condition of payment and should be conducted within a reasonable time of delivery to authorize payment expeditiously.

It should be anticipated that all system components may not be fully operational upon installation and an appropriate course of action should be specified and mutually agreed with the vendor to bring the system to completion.

When the system is operational, production operations can begin. The phasing of production will vary with the applications being developed. Some applications will be implemented immediately, while others may require a period of development or testing. In most cases, a period of parallel operation will take place in which manual operations will continue in parallel until the full operational status of the automated system has been verified.

Throughout the installation and implementation phase, the system manager must maintain strict control over all activities. An implementation plan should be prepared defining the tasks to be performed and responsibilities for each. This plan should be followed and adjusted as necessary throughout the process and progress should be monitored against it.

Checklist for System Installation & Implementation

- Prepare installation plan
- Prepare site for installation
- Arrange delivery
- Accept delivery
- Install system
- Load software
- Conduct acceptance tests
- Install application programs
- Verify database availability
- Conduct parallel operations
- Phase-over to automated operations
- Manage system implementation tasks

(9) DEVELOP DATA BASE

An automated system maintains and relies on a data base containing all of the information used by the system in a computer readable form. The specific form of data base development will be defined in the system design phase. A DBMS may be acquired or programs may be written specifically to manage the data base. Regardless of the technique for managing the data, it will be necessary to develop the data base, that is, to enter the initial set of data so that the system may become operational.

There are three basic approaches to development of the initial data base. In some cases, there is no need for a special data base development task. As the system begins operation, data are entered and over time the data base expands to its full magnitude. In an MPLIS, this approach may be taken in transaction oriented modules such as a building permits system in which permit data are entered from an initial day onward. In the early life of such a system, there are no historical data and therefore no capability for queries to see what permits were issued for this property in the past or if permits have been issued for neighboring parcels or similar buildings. As the system is used, the data will be retained, and over time more and more information can be retrieved so that management and planning applications can be developed.

A second approach, at the opposite end of the spectrum, is typical of GIS systems in which a substantial portion or all of the data base must be developed before the system can become operational. In this case, it is necessary to enter existing and historical data, or as in the case of the GIS, a digital representation of the maps to be maintained and used. Depending on the type of system, this approach to data base development can range from a minor effort to a very expensive and time consuming project. Development of a digital map data base for an urban county can take 2-3 or more years and cost millions of dollars.

A variation on this second approach may be possible if existing digital or computer readable data can be obtained from a system being replaced or from another activity in which similar data are maintained. When this is possible, it can dramatically reduce the time and cost involved. There may still be a requirement to translate the data from one format to another and to augment the available digital data to complete the desired data base.

The third approach is a combination of the prior two. It typically involves operating on a day-forward basis initially, accumulating data for a period of time and then at some later time engaging in a development effort to complete the data base. This approach is effective in cases where there is considerable change occurring and many of the parcels or other items for which data are to be captured will be involved in some action in which the necessary data will be captured. At some point in time a relatively minor effort can be expended to capture data for those entities that were not yet active, such as parcels that have had no development or ownership activity. In some cases, the process may operate in reverse in which a partial data base of high priority items is created initially and the data base is completed from the activities over time.

The development of a data base prior to operation involves several basic steps:

Plan for development project
Establish project staff
Acquire source materials
Prepare source materials
Enter data into system
Conduct quality control verification
Manage development activities

The magnitude of the project will dictate the level of sophistication and distinction between steps involved. In small projects, the steps might be informal and the distinction between them obscure. In a major project, there may be a formal organization, carefully documented plan, and specialists carrying out the various functions.

Plan for Development Project

The development project will begin with a plan. The plan should identify the source materials to be used, a method for obtaining them, preparation tasks required, methods for entering the data into the data base, quality control, and certification. It should assign responsibilities and resources for the various activities and provide a schedule for the project. A mechanism to track the status of the various materials and data base components should also be developed.

Establish Project Staff

If the project is of sufficient magnitude, a project staff and supervision should be established. The staff will be assigned as appropriate to carry out the various activities. The staff may be an existing group responsible for processing information in the current manual operation, a combination of persons from various participating organizations, or a new group formed specifically for the project. The latter approach may be necessary in cases where current staff are fully employed in the ongoing activities that must continue until the data base is operational. A common variation on this approach is to contract for the data base development with a private firm possessing the resources and expertise to carry out the project. In large data base development projects, use of a contractor is often very cost effective and the time required may be minimized.

The staff will require familiarization with the tasks to be performed and may require special training in the operation of the system and/or interpretation of the source materials. Management controls should also be instituted to guide the project and ensure timely, cost effective conduct of the development effort.

Acquire Source Materials

The data base will be created from some form of source materials. The materials to be used will be identified in the data base design and refined in the data base development plan. They may range from existing files or record cards to maps. In some cases it may be necessary to generate the source materials specifically for the project. This may involve a field survey, aerial photography, or other technique. The acquisition of the source materials may have to be scheduled to minimize their absence from their normal location and the impact on ongoing functions. Original materials may have to be handled carefully and accounted for to ensure their safety and security. In some cases it will be necessary to produce copies of all source materials to provide them to the development project.

Prepare Source Materials

In most cases it will be necessary to prepare the source materials in some way to facilitate entry of information. The actual data entry processes themselves are often mass production and high volume. To achieve maximum efficiency, it is usually best to prepare the materials prior to the entry process. It may be necessary to reorganize files or to mark up materials to clarify ambiguities. Data may be abstracted or encoded from original source documents prior to entry into the automated system. In the case of maps that are to be digitized, it may be necessary to redraft some elements and mark others to facilitate production digitizing.

Preparation of the source materials often must be performed by persons who are very knowledgeable about the source materials. Clarification of ambiguities may require thorough knowledge and experience with the materials.

Enter Data into System

Data may be entered into the MPLIS automated system data base in two modes, i.e., from existing digital data files or by manually or otherwise converting paper records into digital form. If digital data are available, they will generally be easier to enter than paper records. With digital data, it will usually be necessary to convert the data from an existing format into a new format for the MPLIS system. The conversion may be simple, requiring only the selection of specific data from the source file and rearranging or reformatting it for the new system. It may, however, be much more complex, requiring conversion from the format and structure of one system vendor to that of another system. It may require extensive programming and use of intermediate files or structure before it can be completed. Existing files may also have to be combined or divided to match the new system structure.

If paper sources must be used for the data base creation, it will be necessary to convert them to digital form. This is generally accomplished at present by manual entry techniques, though some automated methods such as scanning and optical character recognition or vectorizing are beginning to be used. Manual entry will involve keying alphanumeric data into a computer system and editing or verifying it. For map data, manual entry involves tracing the maps on a digitizing table to convert to digital coordinate data.

Automated devices are becoming available that scan source documents using optical, laser, or other technologies to recognize data and convert to digital form. These devices are used for both alphanumeric and map data. The primary problem that still exists with the technology is recognition of patterns or symbology. Converting to digital form with recognition of printed characters is fairly common, but difficulties are still encountered with hand drawn characters. Recognition of line types and other map symbology is still somewhat limited. Where an imaging/document management system is used, it will be necessary to scan some or all existing documents and create the document index.

Since changes may occur between the time that source materials are delivered for conversion to digital form and completion of the conversion task, it will often be necessary to perform an update cycle prior to certifying the data base for operational use. In this cycle, the backlog of map changes that have occurred will be entered to result in a fully up-to-date data base when automated operations begin.

For each data component, it will be necessary to enter information describing the data or "meta data." The meta data to be entered should include descriptions of the data, the source, quality, date of entry, and any other information that will assist potential users in evaluating the suitability of the data for their purposes. The meta data information should be updated as components of the data base are updated to remain continually accurate.

Data entry is generally the most time consuming and costly component of the data base development process.

Conduct Quality Control Verification

Quality control is probably the most important aspect of the data base development process. At each stage in the process, procedures must be implemented to ensure the integrity of the data base being developed. The procedures may be both manual and automated. Redundant entry of data, review of edit listings and plots, and other manual techniques will be used. Automated procedures to verify data by comparing against controls or by performing internal logical consistency checks may be employed. The data entry process and data structure should be designed to allow for maximum automated verification.

Throughout the process, the project manager should maintain records of the entry and quality control activities to allow for verification and audit of the activities. If data entry is performed by a contractor, it will be necessary for the county to establish its own quality control procedures to ensure that the products delivered satisfy the specifications and are entered properly into the data base.

When all data have been entered, quality control procedures are complete, backlog has been eliminated, and all necessary corrections have been made, the data base will be certified for operations. This may occur in phases either for completed geographic areas of the jurisdiction or for layers of sets of features. When certified, automated operations can begin and maintenance procedures must be activated.

Manage Development Activities

In many cases, the development of the data base will be an extensive effort and may include multiple persons and/or organizations. Management of the effort will be significant to success. It will involve assigning all responsibilities identified in the development plan, allocating necessary resources, monitoring activities, and verifying completion of all tasks. The various components of the data base will be divided into work units for management and monitoring. Source materials must be accounted for as they are acquired, prepared, and delivered for conversion to digital format. Completion of digital data must be noted, quality control procedures must be operated, and data must be certified as meeting quality standards. Progress must be monitored relative to the implementation schedule. Throughout the course of the data base development it will often be necessary to modify plans, revise schedules, and reallocate resources as opportunities and problems evolve.

Checklist for Data Base Development

- Prepare data base development plan
- Establish project staff
- Acquire source materials
- Prepare source materials
- Enter/translate data into system
- Conduct quality control verification
- Manage development activities

(10) DESIGN AND DEVELOP APPLICATION PROGRAMS AND OPERATING PROCEDURES

Each functional use of the MPLIS will require specific processing operations. These operations may be simple queries of specific data or may be very complex processing and analysis efforts. The overall MPLIS is a very comprehensive system with a very wide range of capabilities. As such, it is very complex to use with perhaps thousands of commands available to be invoked. To perform the specific operations, and to allow them to be invoked by users who are not computer experts, it will be necessary to develop what are called application programs. Each of the software systems comprising the automated MPLIS will provide one or more command or programming languages that will support the development of specific applications. Each application may be composed of menu selection items to provide the user interface, query functions that retrieve data based on specific selection criteria, processing operations to perform some computation or manipulation of the selected data and display of the resulting data or, in the case of the GIS, a map.

The application programs will be developed in accordance with a method and procedure defined in the system management controls. For very simple applications, a user or programmer may perform the development with minimal control. For more complex application development or modification, a process of scoping, allocation of resources, design, development, testing, user acceptance, and documentation will be followed.

A request for an application will be identified in the initial system design process or by a user following initial implementation. The system manager will review the request, determine feasibility, estimate resources, decide on priority, and allocate resources. When the application is to be developed an assignment will be made to an appropriate person.

In a large and complex MPLIS implementation, CASE (computer assisted system engineering) tools may be used. CASE tools are special purpose programs that are used to facilitate each of the phases in system and application development.

The first step in development will be application design. In this step the developer will interview users, analyze requirements, analyze data sources and flows, identify products, and identify processing components to be used.

The developer will prepare a detailed design of the application, including all input, processing, output and control operations, and all data components. The design will be documented in accordance with system management standards. The design will be reviewed with the users to confirm that the application meets their requirements.

The next step will be development of computer programs to carry out the application as designed. The development may make use of any combination of development tools provided with the systems acquired. These may be programming languages such as COBOL, C, or BASIC, macro languages, the DBMS query language, menu and forms builders, and others.

The developer will enter the proper program code to perform the application operations as designed. The developer may use CASE tools and may use other programming tools provided with the system. The developer should follow a standard development procedure that will facilitate development and ongoing maintenance of the resulting programs.

The developer may prepare a prototype of all or parts of the application to verify the design and to provide a review mechanism for the users. When the users are satisfied with the prototype, the final version will be developed.

The developer will test the programs at appropriate milestones in the process. At completion the entire application will be tested and modified as necessary. The application will then be tested with the user to verify that it satisfies the user's requirements. Any necessary modifications will be made before certifying the application as operational.

Once the user has accepted the application, it can be certified for operation. The data must also be prepared for the application. In many cases the application will draw on data that are already available and managed by the DBMS. In other cases digital data must be converted from existing data files. In yet other cases it may be necessary to convert paper records into automated form and load them into the data base. Or some applications will merely require that the data base structure be defined and data will be loaded as the application is used with no prior data base development requirement.

Checklist for Application Design & Development

- Review application development request
- Authorize application development
- Allocate development resources
- Assign development responsibility
- Review available information
- Conduct requirements analysis
- Define application requirements
- Review and confirm requirements with user
- Prepare application design
- Review and confirm design with user
- Produce application prototype
- Review prototype with user
- Modify design as necessary
- Produce application programs
- Test application programs
- Review application with user
- Finalize application programs
- Document application programs
- Prepare user documentation
- Prepare user training
- Conduct user training
- Prepare application data
- Load application data
- Certify application for operation
- Implement application

(11) CONDUCT PILOT PROJECT(S)

Implementation of an automated MPLIS is often a very large and complex undertaking. It is not practical or desirable to develop the entire system and implement it in a single step. The overall implementation will typically be divided into several phases with parts of the system and data base being developed and implemented in each phase. Within each phase, or as a part of overall system implementation, it is generally recommended that one or more pilot projects or implementations be carried out. The pilot may serve several purposes, but the most common is a test of the operating effectiveness of the system in a limited implementation mode. This may involve only limited functionality and/or use of data for only a subset of the area or data base.

The pilot is designed to test various aspects of the system, including the design of the system configuration, design of the software components, designs of individual applications, design of the data base, operating procedures, update procedures, user interface, and others.

One aspect of the pilot is the recording of information on the experiences, resources, timing, and test results. This information will be used in an evaluation following the conduct of the pilot. The evaluation will be used to determine what changes must be made to the designs, programs, data, procedures, and other aspects of the system.

The pilot should be followed by a redesign or modification stage to incorporate the lessons learned in revisions to the system components and operating environment.

Pilots may be very extensive and complex, involving numerous participants, or pilots may be quite simple involving only the developer and a few users. The conduct of the pilot should be planned in advance at an appropriate level of detail. The responsibilities, test preparation, data preparation, test procedures, information to be recorded, timing, participants, and evaluation to be made should all be addressed in the planning.

Checklist for Pilot Projects

- Determine Pilot project objectives
- Define pilot tests
- Select pilot area and components
- Define pilot evaluation
- Design pilot project
- Assign pilot responsibilities
- Prepare for pilot tests
- Conduct pilot project
- Record pilot information
- Evaluate pilot tests and experiences
- Implement evaluation recommendations

(12) CONDUCT AUTOMATED OPERATIONS AND MAINTENANCE

As the automated MPLIS is developed, installed, and tested, operations will shift to the automated system. Manual activities will be phased out and the functions will be performed with the use of the automated system. As production operations begin, personnel from throughout the participating departments will begin using the system to enter and retrieve data and to perform their various functions.

Management of the system will shift from development to operations. This will involve a change in management procedures and techniques. Operations monitoring and control procedures will be implemented.

It should be noted that automation of the LIS will often involve multiple systems or applications and therefore the transition will not all be accomplished at one time. Individual system components will be acquired and applications will be implemented in some planned sequence and the transition to automated operations will thus evolve over a period of time. This will require that both development and operations management procedures operate in parallel during the transition period.

Maintenance of the automated system will be required in four basic areas: hardware, software, data base, and procedures. The hardware will be maintained primarily by the system vendor through a maintenance contract. Local personnel may be responsible for some maintenance activities and will be responsible for managing the maintenance contract and ensuring that the system is operational at all times.

As hardware problems are encountered or failures occur, the system manager will take appropriate corrective action. All problems should be logged to record status and provide a basis for analyzing patterns. The system manager should be responsible for reporting problems to the system vendor and for invoking the conditions of the maintenance contract.

Software and application programs will be maintained by a combination of vendors and local staff. The basic software systems acquired from vendors will generally be maintained by those vendors through maintenance contracts. The contract will cover problem resolution, temporary fixes to allow operations to continue, and periodic permanent modifications and upgrades to alleviate the problems and enhance capabilities of the software. At various intervals, the vendor will make an updated version of software available. Generally, not all upgrades must or should be installed by the customer. Each upgrade should be reviewed to see if the improvements are significant to the particular installation. If they are, the upgrade should be installed. Over time, an accumulation of changes occur and so it may be necessary to install an upgrade after a few have been skipped to ensure that upward compatibility is maintained.

At less frequent intervals, a major revision or new version of the software will be released and should be installed. Installation of a new version or upgrade of the software will sometimes cause problems with existing data or application programs that must be resolved. This is a reality that must be recognized and planned for with back up copies and warning to users prior to installing the upgrade.

Data base maintenance will occur on a daily basis as transactions occur and are entered into the system. Quality control procedures must be implemented and monitored to ensure the integrity of the data base and to verify quality over time. In most cases, the data base will be maintained by multiple organizations as each enters its data. This places increased importance on the quality control procedures.

The design of the data base and maintenance procedures should incorporate audit trails so that the integrity can be monitored, problems can be traced, and recovery from problems can be facilitated. A formal plan for generating back up copies of the data base should be prepared and procedures for the back up should be implemented. Backup copies should be made at a frequency that will allow the data base to be repaired or reestablished with minimum loss of data. This may involve a hierarchy of partial daily and weekly and full monthly updates, with prior updates replaced by more recent ones. A copy of the data should also be stored at a remote location to allow reconstruction should a disaster strike the computer facility.

Checklist for Operations & Maintenance

Prepare automation phase-in plan
Implement automated operations
Verify automated operations
Establish system management procedures
Establish data base administration procedures
Implement system maintenance agreements
Implement system maintenance procedures
Implement system security procedures
Implement system backup procedures
Implement data base maintenance operations
Establish system monitoring procedures
Review and upgrade system as needed

SUMMARY

Converting from current operations to an automated environment will involve careful planning, numerous tasks, multiple participants, and significant resources. The planning will begin with a recognition of the initial state, determination of the end state goals for automation, and definition of a course of action leading to automation. In most organizations, several departments or functions will be involved, including the city/county manager, information services director, register of deeds, tax assessor, planning director, public works director, building inspector, and sometimes others. These individuals must participate in the planning and goal setting.

At least four conditions may currently exist, ranging from no automation to use of microcomputers to minimal or extensive existing automation. The target for automation may be based on a microcomputer, host, or distributed configuration, and existing automated systems may be integrated, enhanced, or replaced, depending on the requirements of the organization.

The organization for successful automation will involve not only the automation experts from information services, but also the numerous users and management. It will be necessary to assign staff responsibilities and, in most cases, to form one or more committees to incorporate the interests and resources of multiple participating organizations.

Automation will require several types and levels of personnel skills from project management through system and data base management to system analysis and programmers and functional experts and users. These various skills must be available, developed through training, recruited for hiring, contracted as consultants, or some combination of these.

The actual implementation process can be divided in various ways depending on the approach, magnitude, extent, and resources involved. For purposes of this Guidebook, 12 steps were identified and described for the full automation process. Each of these steps can be further divided into multiple subtasks addressing the details of MPLIS automation.

REFERENCES AND ADDITIONAL READINGS

See Chapter 21.

24 MODEL MPLIS

Michael J. Kevany

INTRODUCTION

This chapter presents a description of a model MPLIS installation and the steps through which it was developed. The model is not an actual site, but a composite of the characteristics that might be found in several potential MPLIS installations. The model is described in the following six sections:

Organizational environment
Pre-MPLIS environment
MPLIS development
System configuration
History of MPLIS development
Applications developed

The purpose of this chapter is to provide an understanding of an operational automated MPLIS and its development. It brings together the concepts and components of the prior chapters to indicate what an automated MPLIS is when it is fully developed, so the Guidebook user can have a vision of the target of MPLIS automation. The development of the model MPLIS will parallel many of the concepts discussed in Chapter 23, especially the section "Mileposts or Task Areas of the MPLIS Automation Project."

The model presented is a typical county government, although with very few modifications it might be a city government. Model County, USA, covers 500 square miles and has a population of 200,000 with 80,000 parcels. It has one city of 120,000 and two towns with populations of 15,000 and 12,000. While the majority of the population of Model County reside in the major city and its immediate suburbs, most of the area of the county is rural agricultural land with small to medium size farms of 100 to 500 acres.

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The county provides a full range of services to its citizens, including several services for the city residents. The county is responsible for all property assessment and tax collection, roads, water and sanitation, health, and social services. The county is also ultimately responsible for education, though a School Board is separately elected. The following is a description of the model MPLIS and how it was developed.

ORGANIZATIONAL ENVIRONMENT

The MPLIS implementation involves five direct user departments, a support department, and five additional indirect user departments. The direct user departments are:

Registrar of Deeds
Tax Assessor
Planning
Building
Public Works

Support for MPLIS automation, development, and maintenance is provided by:

Information Services Department.

The five indirect user departments are:

Police
Fire
Parks and Recreation
Utilities
County Manager

The separate School Board also uses data from the county's MPLIS.

There is an elected Board of Supervisors that is the legislative body for the area, establishes policies for county government, and approves the budget for all departments, including utilities and the School Board. The Board of Supervisors appoints a County Manager, who is a professional public administrator. All department heads report to the County Manager, except the Registrar of Deeds and the School Board, members of which are elected.

PRE-MPLIS ENVIRONMENT

REGISTRAR OF DEEDS

The Registrar of Deeds had a manual operation with minimal automation prior to the MPLIS. The Registrar has maintained a Grantor/Grantee Index manually for many years. Ten years ago, the Registrar instituted a procedure in which all deeds have been microfilmed to minimize space requirements. The Registrar provides public access to all records through a public counter.

TAX ASSESSOR

The Tax Assessor has operated an automated Real Estate Master file since the early 1970's. The system was developed internally by the Information Services Department using COBOL programs. The file contained data on ownership and valuation with a record for each parcel in the county. Access to the data was provided through numerous standard screen forms. The data were updated as ownership transactions occurred and when new land and improvement values were established. The primary index key for the Real Estate Master file is a unique parcel number based on map sheet, block, and parcel number. Each record also included a mailing address for billing and a site address, though the latter was often blank.

Prior to establishment of the MPLIS, the Assessor was planning to install an automated appraisal system as part of a countywide revaluation program. The Tax Assessor also maintained a set of tax parcel maps. The maps were at a scale of 1"=200' in the urbanized and suburban areas and 1"=400' in the rural areas. The maps were originally compiled from rectified aerial photography in 1970 by a contractor. The maps were updated regularly by a staff of two persons with other responsibilities as well. New subdivisions and lot splits or combinations were added to the maps in a manual process involving ink on mylar.

The Tax Assessor also used valuation cards with data on many characteristics for both land and improvements, including a sketch of each building. The cards were updated by appraisers based on field inspections. One card was maintained for each parcel.

PLANNING DEPARTMENT

The Planning Department maintained numerous paper files on rezoning, subdivision, site plan, variance, and zoning enforcement cases. It also had a terminal with access to the automated Real Estate Master file and specially designed screens for inquiry. The Planning Department included a mapping group that regularly updated county base maps at scales of 1" = 2000' and 1"=4000', the county zoning maps (based on the 1"=200' and 400' scale tax maps), and a land use map. The mapping group also produced numerous maps in support of general planning studies and rezoning.

The Planning Department regularly obtained maps and data from several other county departments to support its general planning, rezoning, and subdivision processing activities.

BUILDING DEPARTMENT

The Building Department enforces the building codes for the health and safety of county citizens. The department issues building permits for all types of construction, wiring, and plumbing. Prior to issuance of a building permit, the department determines compliance with zoning requirements and the relationship with the officially designated floodplain. It also issues occupancy permits upon completion of construction in compliance with the codes. The department employs a staff of inspectors that responds to calls from builders for each stage of construction.

A few years ago the department acquired a microcomputer-based permitting system. The system was used to fill out the permit and log activity. It had minimal capabilities to support management or reporting, and some staff felt its use was actually a burden.

PUBLIC WORKS DEPARTMENT

The Public Works Department designs, constructs, and maintains all roads in the county, maintains all county buildings and property, and provides trash collection in the unincorporated areas. The department used a manual work order control procedure in which supervisors filled out a form for each assignment. The maintenance foreman or crew member completed the form with information about the job.

The department maintained records on the rights-of-way acquired and owned by the county. It maintained records on pavement and maintenance activity for each road segment and for each county owned building and property.

POLICE DEPARTMENT

The Police Department operated a dispatching operation that included a Computer Assisted Dispatching (CAD) system acquired from a contractor in 1975. The system used a geofile of address range and beat data. The department also maintains records on each incident or call for service that includes a street address or, for traffic accidents, a distance from an intersection.

FIRE DEPARTMENT

The Fire Department also operated its own dispatching center that was primarily manual, using run cards to relate addresses to proper units to be dispatched. The department maintained reports of each call for service. The individual fire companies prepare and update prefire plans with information on all commercial, industrial, and apartment buildings. A team of inspectors also inspects and reports on all commercial and industrial buildings or businesses.

PARKS AND RECREATION DEPARTMENT

The Parks and Recreation Department maintained files for each park site, including land ownership records and site plans and a small scale map of the county with the locations of all parks.

UTILITIES DEPARTMENT

The Utilities Department manually maintained maps of all water and sewer facilities. It also maintained engineering drawings, valve cards, and other records of all significant devices and projects. The department used the same basic manually operated work order management procedure as the Public Works Department. The department had developed an automated customer billing system in the late 1960s. The system operated on the county's mainframe computer and maintained information such as customer name, address, account number, and account status. The primary index was an account number, though each record contained a mailing address for billing.

COUNTY MANAGER

The County Manager regularly requested land related information from each of the county departments. The Manager's office contained a terminal with access to the mainframe, the Real Estate Master, and other data resident on that system, though the Manager rarely used the terminal himself. The Manager generally requested the results of analysis or investigation rather than basic data. A new manager with great interest in automation provided the primary impetus to the MPLIS development.

MPLIS DEVELOPMENT

At the County Manager's request, an MPLIS Advisory Committee was appointed with department-head level representation from each of the primary departments and police, fire, and utilities. The Committee was charged with planning for the development of an automated system or systems for managing the county's land records. The charge included an objective that data would be shared by multiple organizations to the greatest extent practical and that redundant operations would be eliminated. The Planning Director was appointed as Chair of the Committee.

The Advisory Committee in turn appointed a Land Records Automation Technical Committee made up of technical staff members from each participating department. The role of the Technical Committee was to carry out a needs analysis and conceptual design and to prepare a development plan.

The dynamics of these committees were influenced by the personalities of the members and the relationships between and among organizations. Some of the significant conditions follow. The Planning Director was well respected in general, but thought of as a data junkie. He also had very little knowledge of automation. The Information Services Director was very defensive and protective of his automation empire. There was great dissatisfaction among users with the quality of service, however. Very few systems were operational. Response time for new system development or existing system modification was very long. There was almost total dependence on the Information Services Department for all development, maintenance, and modification.

The Tax Assessor was independent of all other departments and not very cooperative in prior countywide endeavors. He insisted that the legal requirements of his function did not allow activities that would negatively impact his work.

Utilities, as an enterprise organization, generated its own revenues and was concerned that it might be pressured to fund the GIS.

The Registrar of Deeds and Public Works Director also operated in very independent ways, as did Police and Fire. The Police Department operated a separate computer system for its functions, and the Police and Fire departments guarded their separate dispatching operations.

Following the decision to develop the MPLIS and preparation of the implementation plan, a core MPLIS support group was formed in the Information Services Department. The core group consisted of an MPLIS manager, who also served as the initial system manager and data base administrator, and three application development programmer/analysts. The MPLIS core group was charged with carrying out the MPLIS Implementation Plan and was instructed to support the MPLIS Coordinating Committee (that replaced the original MPLIS Advisory Committee).

The MPLIS Coordinating Committee after it evolved was composed of the Director or a deputy of each of the participating departments (Registrar, Assessor, Planning, Building, Public Works, and Information Services) with all other department heads welcome to attend meetings. The chair of the Committee rotates each year through election by the members. The Coordinating Committee sets policy on all MPLIS related issues, establishes priorities for development activities, and updates the MPLIS plan.

The MPLIS Technical Committee addresses technical issues as they are encountered in MPLIS development, implementation, and operations. The membership of the Committee includes technically knowledgeable persons from each participating department and is augmented as special technical needs are encountered.

Each of the participating departments has assigned a key person to manage or coordinate MPLIS resources and activities within the department, to participate in the Technical Committee, coordinate activities with other departments, and in some cases to develop applications for users within the department. In a few departments (Assessor and Public Works), two or more persons are assigned to MPLIS activities on a permanent, full-time basis.

Mapping for the County has been consolidated within a newly created GIS Support Group in the Planning Department. Four persons have been assigned to make all updates to maps in the county and to manage the GIS mapping activities. Maps updated by this group include the parcel maps, zoning, geographic base file (GBF), and small scale base. The Utilities Department continues to maintain its water and sewer maps as layers in the countywide GIS data base.

SYSTEM CONFIGURATION

The MPLIS system configuration has evolved and grown in the few years since its initial installation. The county operated a mainframe host processor prior to the MPLIS project. The mainframe has continued to serve as a key resource in the configuration. The MPLIS plan adopted a distributed configuration that incorporated the mainframe along with other servers and numerous terminals, microcomputers, workstations, and peripheral devices. One server was assigned to manage the GIS graphic data base and another for the document management data base.

User access to the MPLIS is provided through a combination of terminals and microcomputers that are linked to the data base and processors through a communications network. The various peripheral devices such as printers and plotters are also linked to the communications network.

The Communications network is composed of a "backbone" wide area network (WAN) that links the various county buildings with each other. Within each building and, in the case of the administration building, each floor, are local area networks (LAN) that link the various devices with each other and with the main WAN.

HISTORY OF MPLIS DEVELOPMENT

The development of the MPLIS in Model County occurred in several phases over a four-year period, and as a "living" system it continues to evolve and grow today. The development can be divided into five phases, beginning with the formation of the MPLIS Committee by the new County Manager. The five phases are:

Planning and analysis
Basic capability acquisition and development
Application development
Continuing development
Operations and maintenance

While the plan that guided system implementation identified specific phases, the actual development did not match those phases precisely. In reality, development and implementation occurred as a continuous process over four years, with periods of high activity and lulls in activity. While the implementation plan identified specific tasks, orders, and priorities, much of the development was influenced by opportunities and constraints that were encountered along the way.

PHASE 1: PLANNING AND ANALYSIS

One of the initial activities of the MPLIS Committee was the conduct of a requirements analysis. A team of individuals from each of the participating departments was formed to analyze needs for MPLIS automation within each department. The activities of this group were guided and coordinated by representatives from the Information Services Department. While this effort resulted in a basic understanding of requirements and provided an awakening regarding the magnitude and complexity of the endeavor, the findings were not adequate for immediate system development. The persons assigned continued to have responsibilities for other functions and so were only able to devote limited time to the needs analysis. Most of the participants were not system analysts and a few had little interest in the assignment. The results, therefore, varied widely across departments in depth and quality of information generated and substance of analysis performed.

This experience indicated to the Committee that there were significant benefits to be gained from automation of land information throughout the county. It also indicated, however, that the successful development of such a system would require considerable technical expertise beyond that available in the County. While the Information Services Department had a staff of system analysts, they were fully occupied with ongoing development and maintenance activities. It was thus decided that a consultant would be retained to augment County resources.

The MPLIS Technical Committee was thus formed to assist in acquiring the services of a qualified consultant with ongoing responsibility to guide development of MPLIS automation. The Technical Committee reviewed the potential requirements identified in the needs analysis, with assistance from Information Services Department representatives, identified the skills required, contacted other counties to obtain information on their approaches to the problem, and sought guidance from a few state agencies and two Federal agencies, the National Geodetic Survey (NGS), and the U.S. Geological Survey (USGS). Based on this research, the Committee formulated a Request for Proposals (RFP) for consulting services for an MPLIS automation requirements analysis, an implementation plan, and assistance in implementation. A few of the important pieces of advice obtained from those with experience were:

Be sure the consultant actually has extensive experience with MPLIS automation projects; there are many unique issues to be dealt with.

Be sure the consultant has adequate skilled staff to perform necessary services.

Be sure the consultant actually provides the experts offered.

Check consultant references carefully.

Be sure the consultant is objective, not attempting to guide toward a future sale of hardware or software or data base development services.

Select a consultant carefully and then place confidence in the services.

Participate actively with the consultant, reviewing intermediate products and learning from the experience.

Within the constraints of procurement regulations, operate open communications with potential proposers, the more information they have, the better the proposals and more effective the selection process.

The RFP was issued to a list of potential consultants compiled through the research effort, information from other counties, and contacts with candidate firms. The RFP specified the services to be provided and the terms of service very clearly. The RFP also specified a format for proposals to be submitted by consultants. The RFP conformed with the County's procurement procedures and the Procurement Officer played a key role in the selection process.

A consultant selection team was formed to evaluate the proposals and recommend a consultant to be retained. The team established an evaluation procedure and identified evaluation criteria for each aspect of the proposal and evaluation.

Seven proposals were received from a variety of consultants. Following an initial scoring of proposals, a short list of three firms was identified. In-depth reference checks were made of these three. Each was also invited to an interview in which the proposals were reviewed and ambiguities were clarified. A final meeting was conducted among selection team members to discuss the proposals, scoring, and to select a recommended consultant. While members had differing perspectives and interests, it was possible to achieve a consensus on the consultant to be selected.

The recommendation of the selection team was forwarded to the MPLIS Coordinating Committee and the findings were presented to the Committee. The Committee ratified the recommendation and the County Procurement Officer negotiated the contract.

The consultant contract had four basic tasks along with various project management and reporting responsibilities. The four tasks were:

Perform requirements analysis
Perform conceptual design & feasibility study
Prepare strategic & implementation plan
Establish organization & train staff

These four tasks correspond to the first four task areas of the MPLIS automation project as discussed in Chapter 23.

The contract was negotiated and executed with the selected consultant. The project began with an initiation meeting between the County and consultant project managers. At this meeting, the work plan and schedule were finalized and agreement of tasks, products, and schedule of initial contacts between county and consultant personnel was reached.

(1) PERFORM REQUIREMENTS ANALYSIS

The consultant initiated the project with a workshop on the project methods and the relative roles of county and consultant personnel. Following the workshop, the consultant conducted a series of interviews with appropriate representatives of the participating county departments to collect information on the county's MPLIS automation requirements. The consultant collected information on current data, information systems, and resources. The consultant also distributed questionnaires to the participating departments for the collection of specific information.

The consultant analyzed the information collected to identify the automation requirements. Requirements were categorized into six areas:

Business functions performed
Data to be collected and managed
Data flows and relationship
Processing operations to be performed
Products to be generated
Organization(s) and staffing to be established

The requirements were identified at a relatively general level for planning purposes. A report was prepared by the consultant and presented to the county for review and comment. Most departments participated actively in this review and benefited from that review throughout the project. A few departments did not participate actively at this stage and suffered difficulties later due to requirements that were overlooked at this step.

(2) PERFORM CONCEPTUAL DESIGN AND FEASIBILITY STUDY

Based on the requirements identified, as revised by the county, the consultant prepared a conceptual design for the automated system. The conceptual design presented an overall configuration for the MPLIS, identified components for each participating department, defined the data base required for the potential uses, and described the operating concept of the system, including the sharing of data and system resources. The basic configuration selected was a distributed configuration with multiple processors and servers interconnected through a communications network.

One of the key aspects of the conceptual design was the integration of all components, including the integration of existing automated resources to the greatest extent practical. One of the problems encountered with this policy was the dramatic changes in technology that have occurred since installation of the current mainframe system with its COBOL-based application programs. To accommodate this technology, it was necessary to design linkage to the mainframe in the communications network, define mechanisms that would support linkage to that type of system, and incorporate software to allow access and exchange of data with that system.

As with the requirements analysis, the consultant presented the conceptual design to the county for review and comment. Also, as with the prior report, the county review was important to subsequent implementation success.

(3) PREPARE STRATEGIC & IMPLEMENTATION PLAN

Based on the requirements, conceptual design, and analysis of available resources, organizational structures, and priorities established by the county, the consultant prepared a plan for the implementation of the automated MPLIS. The plan defined a series of tasks to be performed, identified responsibilities for the tasks, estimated resources required, defined an MPLIS implementation organizational structure, and presented a schedule for the implementation project.

The implementation plan was presented to the MPLIS Technical Committee in a workshop environment where it was critiqued and modified to meet the needs of the participating departments. The resulting plan was reviewed and confirmed by the MPLIS Coordinating Committee. As a result of the plan, the committee structure was modified. The permanent MPLIS Coordinating Committee was established with responsibility to guide the development effort and coordinate the activities of each of the participating departments.

(4) ESTABLISH ORGANIZATION & TRAIN STAFF

The County used the recommendations in the Implementation Plan as the basis for establishment of an MPLIS implementation organization. The organization included the overall MPLIS Coordinating Committee to guide and coordinate all MPLIS activities. The Committee is composed of senior management representatives of each of the MPLIS user departments. Staffing for the MPLIS implementation project was assigned primarily in the Information Services Department. The staff consisted of an MPLIS Project Manger, a system manager, data base administrator, and three analyst/programmers. These persons had specific responsibility for the MPLIS automation and were assigned full time. Each of the key MPLIS user departments assigned one person as the key departmental person to serve as liaison with the core staff and other departments, and to perform or manage MPLIS activities within the department.

One person with extensive MPLIS experience and skills was recruited from outside the county as the MPLIS manager. The remaining staff members were reassigned within the county. A training plan was prepared to provide a mechanism to prepare staff to develop the skills necessary for MPLIS implementation, operations, and maintenance support. Specific training was scheduled for each staff person. A series of general overall MPLIS automation orientation sessions was prepared and conducted for all interested county staff.

The staffing of the MPLIS project worked reasonably well, though some problems were encountered. The existing Information Services staff had some difficulty adapting to the new technology to be employed for the MPLIS. One person had great difficulty and eventually had to be reassigned. Some resentment to the hiring of the outside expert also emerged. The requirements for training evolved to become significantly more extensive than was originally anticipated.

Personnel in a few departments became very proficient in MPLIS automation techniques and performed important development functions within the departments. Implementation in other departments suffered because no internal capabilities were developed and the department was completely dependent on the services of the Information Services Department.

PHASE 2: BASIC CAPABILITY ACQUISITION & DEVELOPMENT

This phase includes task areas (5) through (9) of MPLIS automation as discussed in Chapter 23.

(5) DESIGN SYSTEM

While the MPLIS made extensive use of the existing mainframe and several microcomputers, it was necessary to augment these resources with additional hardware components. The conceptual design of the MPLIS called for new software technology that was not available in the county at that time. The focus of the new technology was a commercially available relational data base management system (RDBMS). A GIS was to be incorporated into the MPLIS as well. The planned configuration was to be distributed to provide direct access to all system and data base resources for each participating department. To support that design requirement, it was necessary to acquire and implement a sophisticated communications network.

The conceptual design provided an overall framework for the design of the system. In addition, it was necessary, in this phase, to prepare a detailed design which would include the specifications for acquisition of the necessary hardware devices, software components, and communications facilities.

The detailed design required collection of additional information on the specific requirements within each functional area. This was accomplished through a review of the information collected for the conceptual design, interviews with personnel in each functional area, and analysis of descriptions of existing systems, forms, and source materials. This information was analyzed in depth to develop the detailed system design specifications.

The design was specified at this step as functional requirements for hardware, software, and communications capabilities. This was done to allow multiple vendors to propose systems for acquisition. The specifications of existing resources that were to be integrated into the MPLIS were also defined as a part of the system design. The design included an overall configuration diagram, specifications for each hardware device and software component, and a definition of the operating environment in which the system was to be implemented. The design specifications were documented for incorporation in a request for proposals for acquisition of the necessary system components.

(6) DESIGN DATA BASE

A similar set of tasks was performed to prepare the detailed specifications for the MPLIS data base. Information was collected regarding data base requirements during the design interviews noted above. The conceptual design was used as a guide to the data base design. A thorough review and evaluation was made of the potential source materials to determine their suitability for incorporation in the data base. The source materials included existing digital files currently being maintained on the County's mainframe, several microcomputer data bases, various paper files, sets of forms, and existing maps.

A detailed review was also made of current and potential data updating sources and procedures to determine their value for the automated MPLIS and to provide the basis for design of automated update procedures. In some cases, current automated update procedures were adequate with little or no modification. In others, new sources and procedures had to be identified. In the case of the source maps for the GIS, it was determined that the existing planimetric and topographic (contour) maps that were more than 10 years old were too outdated to serve as an accurate source. Therefore, a new aerial photography and photogrammetric compilation project was recommended in the design. The existing parcel maps were also found to be inadequate. The current tax maps were felt to be complete, identifying all parcels. However, they were not spatially accurate, having been compiled from simple rectified photography more than 10 years ago. It was recommended, therefore, that they too be recompiled, this time being fitted to a new set of orthophotos of the county. The new mapping was also designed to be compiled in North American Datum (NAD) 83 State Plane Coordinates, rather than the NAD 27 datum used for the existing maps.

Several sets of documents were identified for inclusion as raster images in the data base. These included plats, assessor cards, engineering drawings and development administration case forms. It was decided that the Registrar of Deeds records would also be converted to an automated document management system replacing the current microfilm in the future with all records referenced to the PIN. A logical data base design was prepared in a manner that could be used to support specification of a physical design once the RDBMS and GIS were selected and acquired.

(7) ACQUIRE AUTOMATED SYSTEM COMPONENTS

Acquisition of the hardware, software, and communications system components began with the detailed design and the preparation of functional specifications. Most of this work was performed by the consultant with participation of the Information Services Department staff.

The functional specifications were then incorporated into a Request for Proposal (RFP). The initial acquisition was for the basic capabilities for development of the automated MPLIS and specific components for a few high priority functions. The configuration was to be augmented in multiple subsequent phases, though the intent was to acquire most components through the initial procurement mechanism.

The acquisition was conducted in accordance with the county's procurement procedures, though several adaptations had to be made to accommodate the unique requirements of this particular type of system procurement.

A selection team, similar to that of the consultant selection, was formed. The team was composed of representatives of Information Services, Assessor, Planning, Registrar, and Public Works. The Procurement Officer guided the selection process and the consultant provided technical assistance.

The procurement involved several steps, including proposal evaluation, reference checking, short list, interviews, demonstration/benchmark tests, and numerous team meetings.

The following were some of the key experiences of the selection process:

Some team members were initially intimidated by the technical nature of the assignment, though the Information Services team member provided necessary technical guidance.

Most team members gained a valuable education through the process.

Differentiating the practical realities from the sales information was difficult.

Vendors were very cooperative throughout the process.

All vendors thought they should be selected and protests were threatened by the losers.

Useful benchmarks were difficult to conduct.

Structured formats for proposals were essential to evaluation.

Providing vendors with flexibility to incorporate differing approaches while configuring a solution was difficult to balance with a structured, objective scoring procedure.

Extensive communication with the vendors was important to understanding both the requirements and the offerings.

A lowest bid approach to selection would have been a disaster.

Accommodating the widely differing interests and knowledge of the team members was a serious challenge to the selection team chairperson.

In spite of these challenges, and with the assistance of the Information Services and consultant experts, the team was able to reach a consensus on the vendor to be selected and a recommendation was formulated for the MPLIS Coordinating Committee. The entire process took six months. Negotiating a contract and gaining its formal approval took an additional six months.

The initial acquisition included one server device; mass storage; 12 workstation/microcomputers; a RDBMS; the communications hardware, wiring, and software packages; and various peripheral devices.

(8) INSTALL AND IMPLEMENT SYSTEM

The implementation of the automated MPLIS was a complex process that lasted three years. The acquisition described above was for an initial configuration of hardware and software. That configuration was installed to support a few of the highest priority applications and to provide the basis for development of the overall MPLIS. The initial configuration was installed about four months after contract execution. Acceptance tests were conducted to verify that the configuration satisfied the contract specifications and was fully operational as installed.

Following acceptance testing, key members of the county staff received a series of training classes provided by the vendors. The classes covered management of the system, the operating system, the programming languages provided (BASIC and C), and the RDBMS. The system manager, data base administrator, and programmer analysts received the training. Unfortunately, some of the persons were not able to devote additional time to practice what was learned in the classes, and thus the time required to achieve full productivity was delayed.

As part of the implementation process, a set of system management and data base administration procedures was designed and developed. The procedures followed the patterns of existing Information Services Department procedures. However, major modifications were required to accommodate the distributed nature of the configuration with multiple data storage locations and the continuous transfer of data between the various nodes in the network. The anticipated future installation of the GIS components of the system also required modifications and enhancements to the data base administration procedures primarily to accommodate the graphic map and topological definition portions of the data base.

The system was first implemented in the highest priority functional area, the Assessor's office. A parcel data base was created using the RDBMS. Data for each parcel in the County were loaded into the data base. The initial loading was of the data in the existing parcel-based Real Estate Master file. That file provided data for each parcel in the County. During later data loading and verification, however, problems were encountered and it was discovered that the Real Estate Master file did not in fact include data for some parcels that had been combined for taxing purposes, a commonly encountered problem in MPLIS development.

A set of automated procedures (applications) was designed and developed for daily updating of the data base. The updating application incorporates significant improvements over the prior file program. One of the key improvements is in the archiving of data and recording of the chain of title. The latter capability was facilitated greatly by the concept of the parcel identification number (PIN) and its assignment to all land records.

In addition to the updating application, a query and reporting application was developed for the Assessor and others. The application allows a user to retrieve and display parcel information by entry of a PIN, address, or other selection criteria. The application uses the standard query language (SQL) of the RDBMS. It allows a user to easily enter qualifying criteria such as parcel value and size, and a geographic area from which to select parcels that meet these criteria.

From this initial implementation the system has grown, expanded, and evolved. Each year additional components are acquired. Major milestones were the acquisition of the GIS in the second year and of the image/document management system in the fourth year.

(9) DEVELOP DATA BASE

Data base development has been a major aspect of the implementation of the MPLIS. The data base development can be divided into five areas:

Incorporation of existing digital data
Entry of data from existing forms, files, and records
Day-forward entry of transaction data
Creation of a digital map data base for the GIS
Creation of the image/document management data base

Each of these areas provided necessary data for various applications and functions of the MPLIS. Each posed its own problems and requirements for resources and solutions.

The *incorporation of existing digital data* was the approach taken for the initial data base development. As noted above, the first data file to be loaded into the MPLIS data base was the existing Real Estate Master file. This process involved translating the data from the mainframe data structure to the RDBMS and loading into the RDBMS schema. As with all steps in data base development, a thorough quality control procedure was also invoked. The two data sets were also maintained in parallel for an extended period, until the MPLIS updating application was fully functional and its accuracy was verified.

Other existing land-related data files throughout the county were eventually converted and loaded into the MPLIS data base as the applications that would use them were developed and implemented. Each required the definition of the RDBMS tables and some level of translation or restructuring. As the various sets were loaded and integrated through the RDBMS, several problems and errors were discovered. As the files had been used independently, many of the errors had not been noted previously. Comparison of the various files, however, revealed inconsistencies. A significant effort was required to reconcile and correct the errors discovered.

For some applications that had not existed in an automated form before, it was necessary to key *enter data from existing forms, files, and records*. In these cases, a mass production process was generally developed. The process included the development of entry forms, entry procedures, editing and quality control procedures, and data base loading procedures. In some cases, it was necessary to decide how far back to go in entering historic data. The requirements of the application determined the extent of historic entry. For some applications, a basic set of factors was needed. For others, the past year's activities were adequate. And for some, a complete picture of the situation as it existed at implementation time was necessary.

The most straightforward data base effort was the *day-forward entry of data* as the various applications were used. In these cases, there was no need for translation, though, where the data were related to existing data sets, some errors and inconsistencies requiring reconciliation were discovered. Applications were developed and implemented. Data for the application were entered as transactions were performed. In some cases, the newly entered data were related to existing data held in the MPLIS data base. As an example, one standard operation was the verification of all address data. When an address is to be entered as part of an application transaction, it is first compared to the master address register. If the address is found, it is entered into the new data record. If the address cannot be found, similar candidates are displayed for the user to select. If, for example the street name is misspelled, the correct spelling can be entered in this process.

By far the most time consuming and costly data base effort was the *creation of the digital map base for the GIS*. The existing maps in the County were of generally poor quality. Some, such as the tax parcel maps, had been produced initially from unrectified photography and, therefore, had a low level of positional accuracy. Others, such as the planimetric/topographic maps, were badly outdated. Yet others suffered problems such as the small scale of the floodplain maps or the felt marker lined administrative district maps.

To create the GIS data base, it was necessary to conduct an aerial photography project. The aerial photography was used to compile new planimetric and topographic data in digital form and to produce orthophotos that were used as the control base for recompilation of parcel maps.

The GIS data base effort was carefully planned by a consultant with extensive experience in photogrammetry and GIS data base development. A set of detailed specifications was produced, reflecting the requirements for the GIS data. The specifications addressed the map feature and nongraphic contents to be acquired, the map scales and accuracies to be achieved, the topological definitions to be generated, and the cartographic standards to be employed.

The specifications were incorporated in a RFP for mapping services and a careful procurement process was conducted. Qualified vendors of such services were invited to make an offer, describing their capabilities and approach. The best qualified firm was selected through an evaluation of proposals, reference checks, and interviews. Negotiations were conducted with that firm and a contract was executed. As with the system acquisition, the selection was not made on the basis of the lowest bid price.

The aerial photography was restricted to a relatively narrow time window in the spring when conditions were right for photography. This reality had to be accommodated in the implementation plan timing and it was necessary to adhere to that part of the schedule or a year would be lost. Fortunately, the bureaucracy and the climate cooperated and the aerial photography was performed on time.

A crucial element of the photogrammetric project was the establishment of the geodetic control network at an adequate density to support MPLIS requirements. Initially this was adequate density to support photogrammetric control for mapping at the scale of 1"=100' and 400' and accuracy (+/-5' and 20') required. A longer term requirement was adequate density to tie land surveys and others at reasonable cost. This was determined to be 1/2-mile spacing in the developed areas and 1-mile spacing in the rural areas. A GPS project was undertaken to provide the basic framework that could be further densified over time. It was necessary to install 65 first- and second-order control points for the photogrammetric project.

To observe some of the required features, including the geodetic control points, in the photography it was necessary to mark those features on the ground. This was done by placing targets on the control points and painting such features as manholes and hydrants for clear visibility in the photographs.

The contractor established the control, produced the aerial photography, performed the analytical aerotriangulation, compiled the planimetric and topographic features, and produced the orthophotography. The County instituted a thorough quality control procedure for all products. The procedure included visual inspection of check plots, automated edit of digital data, and some limited field surveying of check points.

As with all other aspects of MPLIS development, many problems were encountered. Some features had not been properly marked for the photography. The translation of data from the format of the stereoplotter to that of the County's GIS brought some anomalies, particularly where the topological definitions had been established. Some anomalies among features were also encountered. Some features were not captured in the most effective way.

When the orthophotos were produced, the contractor overlaid the parcel maps and recompiled them to match the orthophotos. Where significant discrepancies were encountered, the contractor researched the deeds and plats to support recompilation. The resulting overlays were digitized, annotation was added, and the topology of the parcels was defined. A PIN was established for each parcel and used to link the nongraphic data about the parcel. Again, the county mounted a significant quality control procedure to verify the work of the contractor.

The image/document management data base was created in a similar manner to the digital map data base. Specifications and a RFP were prepared, and a conversion contractor was selected through an evaluation process. The specifications described the documents to be converted, the indexing to be performed, the format of the deliverable digital files, and the quality standards to be met. The RFP invited proposals from numerous firms. The evaluation included the resources of the firms, the proposed conversion method, past similar experience and conformance with the specifications provided.

A carefully planned procedure for delivery and control of source materials was critical to the success of the conversion effort and maintenance of the security of the records. All documents were delivered to the contractor who performed the scanning, indexing of records to PIN and other indexes and quality assurance. The County planned and conducted a quality control procedure also prior to acceptance and loading of the data. This required a problem resolution procedure to correct problems detected in the contractor's and the County's verification procedures.

The resulting raster data were loaded into the data base and the linkage identifiers were established between the RDBMS, GIS and image data bases.

PHASES 3 AND 4: APPLICATION AND CONTINUING DEVELOPMENT

Phases 3 and 4 correspond to task areas 10 and 11 of MPLIS automation discussed in Chapter 23.

(10) DESIGN & DEVELOP APPLICATION PROGRAMS & OPERATING PROCEDURES

Application development has been a continuous activity since the initial parcel data updating application described above. The initial implementation plan identified numerous applications to be developed throughout the county. It also identified a set of high priority applications to be developed in the initial phase of implementation.

A methodology was defined, tested, and refined for application design and development. Like other aspects of the MPLIS automation, the methodology most useful for this configuration was quite different from the conventional methodology that had been used successfully in the county for the prior systems. The availability of off-the-shelf software, a sophisticated RDBMS, macros, and other development tools and the distributed nature of the data base and software management all placed special requirements on the development methodology. Initially a CASE tool was tried for development, but some of the tools proved difficult to use in this environment. A modified methodology with use of a few of the CASE tools was finally established.

An important aspect of the application design and development is the intimate involvement of users in the process. Since the MPLIS applications are generally operated by the end users, rather than a data processing support group that generates reports, it has been necessary to obtain active participation of the users in the design and development process. Prototyping is also used as a development tool. In this approach, a basic or skeletonized version of the application, or parts of it, is developed and demonstrated for the user. The user provides comments on the prototype which are then used to complete the application. This approach allows the user to view the actual operation of the system and help guide the development of the applications. The applications developed are described later in this chapter.

(11) CONDUCT PILOT PROJECT

A pilot project is a commonly used technique to explore a new technology and verify its usefulness and proper design prior to embarking on a major system implementation. Model County actually conducted several "pilot projects" throughout the implementation of its automated MPLIS. An initial pilot was conducted with the first application to verify the operational status of the system components. The data base update and maintenance procedures were conducted on a test basis. During the pilot project, all aspects of system operation were observed carefully to determine if all components were operating properly and to identify improvements that might be made in system, data base, and application designs. The effort required to develop application programs and perform various system operations was measured to assist in planning for further development and for allocation of resources to ongoing operations.

Several important lessons were learned during this initial pilot. Among them was the reaction and capability of the system users. It was discovered that more extensive training was required than had originally been anticipated. Numerous "quirks" in the data were discovered as the change transactions were entered. Several modifications were required in the data base design and capture and entry procedures to cope with unexpected anomalies.

As each application was implemented, it was operated in a pilot or test mode prior to full implementation. Applications that replaced existing operations were operated in parallel with the manual operations until there was full confidence in their operational effectiveness. In each case, valuable lessons were learned from the "real world" operations that were used to improve the quality of the operational version of the applications.

Perhaps the most extensive "pilot project," and the most necessary, was the GIS pilot. Development of the graphic map portion of the GIS data base posed numerous problems. The variety of quality, scale, and format of existing maps was such that integration of the various parcel, utility, administrative, and environmental map features was very difficult. In addition, the new planimetric and topographic data had to be compiled.

To verify the data base development procedures, a small area was selected for which the map data were compiled, registered, and digitized. The procedures for compilation and digitizing and the data base design were carefully evaluated and modified to accommodate the lessons learned in the pilot.

Several problems were encountered, including areas that were on the source parcel maps, but which had no identifier and no related records in the Real Estate Master file, buildings that overlay parcel boundaries, adjoining parcels whose survey descriptions were incompatible, road rights-of-way whose boundaries didn't match adjoining parcel boundaries, utility manholes without identifiers, manholes depicted on source maps that actually no longer exist (according to the latest aerial photography), and sewer lines that ended incorrectly on the source maps.

While the conversion of the graphic lines and symbols from the paper maps to digital form was relatively easy, the assignment of the "intelligence" in the form of identification keys and topological structures was much more difficult. Several ambiguities existed in the source materials that were not apparent until the attribute data were assigned or the logic of connectivity or polygon closure was defined. The linking of existing digital data and paper records to graphic features exposed numerous inconsistencies. A major lesson learned was how County personnel had adapted over the years to making use of maps and records with such a large number of errors.

In terms of the GIS data base, the pilot was invaluable. Several data conversion procedures were modified, the data base definition was modified in numerous areas, and some hard decisions were made to forego capture of data for which no adequate source existed.

When the pilot area data base was available, a pilot project was conducted for the use of the GIS. A few key applications were developed and tested in operation by the end users. As with the other pilots, the activities of the pilot were carefully monitored and evaluated. The time and resources required to develop applications were recorded and used for future planning and management. The experiences of the users, in particular, with this new technology were monitored and evaluated. As with earlier pilots, the need for greater training was noted. Some users were not able or willing to use the technology effectively. On the other hand, most users expressed an enthusiasm for this graphically oriented technology that went well beyond the response to more conventional systems.

PHASE 5: CONDUCT AUTOMATED OPERATIONS & MAINTENANCE

This phase corresponds to task area 12 of MPLIS automation as described in Chapter 23.

As each module of the system was developed and tested, the operations related to it were converted to automation. All hardware devices were installed, tested, and certified for operation. All software components were developed, implemented, tested, and certified for operation. All data base sets were also developed, loaded, and certified for operation. The personnel involved in all aspects of the operation were trained in the automated procedures and all tasks necessary to operate or support the applications were developed. Once these were completed, the applications of the module were prepared for conversion to automation.

In most cases, the phasing in of automated operations involved concurrent operation of both the new automated procedures and the prior automated or manual procedures. Once the new procedures were proven to be fully operational, the parallel prior operation was terminated. In a few cases, rather significant redesigns and redevelopment were required before the application could be certified for operation.

As a part of system management and data base administration, a set of design modification procedures were developed and implemented. These procedures allow a user to request a modification in the design of an application or data base component. The required modification and its impact on other system components are evaluated and a decision is made regarding the modification. If authorized, resources are allocated and the modification is developed and implemented. A similar procedure was implemented to support requests for new automated applications or additions to the data base.

APPLICATIONS DEVELOPED

Numerous applications of the MPLIS have been developed for the participating departments throughout the county. Some of the applications are very simple and were developed by user or support staff in a few hours. Others are very complex and required several person months of effort to develop. Some applications were developed for specific functions within individual organizational units, while a few general or core applications serve numerous functions in several organizational units. The following is a discussion of the MPLIS applications in Model County, beginning with the general core applications and a specific example.

CORE APPLICATIONS

A few core applications have been significant to the usefulness of numerous departments and functions. these include:

General Inquiry
Address verification

The general inquiry application allows a person who is not a skilled programmer to make an inquiry following a predefined set of menu options to retrieve and display data from the MPLIS data base. The application operates by providing the user with menus of commands to select and forms for entry of parameters of data. The user selects commands by pointing at menu options. The user also enters parameters in response to prompts displayed on the screen. An example of such an inquiry is as follows:

Menu selection: Parcel Data
Selection parameter: enter Site Address
Display options: Standard Parcel Report
Display results:
  Owner Name: Lincoln Node
  Address: 111 Croswell Street
  Bldg Type: Single Family
  Land Value: $35,450
  Imp Value: $110,000
  Last Sale: $$95,000
  Sale Date: 9/9/79

A wide variety of data choices and display formats are available with this application, through the simple selection of menu options and entry of control parameters.

DEPARTMENT SPECIFIC APPLICATIONS

Numerous department-specific MPLIS applications were developed. The major applications are listed for each department in Model County.

Registrar of Deeds
- Grantor/Grantee/Parcel index
- Development activity index
- Public inquiry access
- Remote index access

Tax Assessor
- Assessor inquiry
- Sales display
- CAMA interface
- CAMA
- Valuation neighborhood definition
- Parcel map updating
- Appraisal routing
- Field map generation
- Public inquiry access

Planning
- Development case tracking
- Subdivision review
- Rezoning support
- Zoning map maintenance
- Land use mapping
- Historic site inventory
- Economic development support
- Public facilities planning
- Environmental analysis
- Public hearing notification

Building
- Permit issuance and tracking
- Inspection scheduling
- Development reporting
- Violation tracking

Police

Geofile updating
Incident mapping
Beat definition
Emergency dispatch support
Workload management

Fire

Emergency dispatch support
Hazardous materials inventory and tracking
Fire station location
Incident mapping
Inspection scheduling and tracking
Emergency response planning

Parks and Recreation

Facility inventory
Facility scheduling
Facility planning
Real estate records management
Maintenance scheduling

Utilities

Facilities inventory
Maintenance management
Records management

SUMMARY

One of the key lessons the county learned over the past few years of MPLIS automation experience was the rapid change in the technology. Over the four-year period since initial implementation, the county has loaded numerous versions of each software product, implemented a few major upgrades requiring significant effort, upgraded many of the hardware devices, and replaced others with new versions. The county has made major improvements to its overall system through upgraded technology capabilities that were not available when the system was originally acquired. While most of these enhancements have been positive, none was without some level of difficulty and some were very "painful." One of the interesting phenomena of MPLIS automation is that there is always a new version about to be released that will solve the problem or that will provide some wonderful new capability.

In many cases, the realities of development and operation were quite different than original expectations. Many unanticipated problems were encountered in the development and operation of the automated system. While the data base design calls for the integration of sets of data, the reality was that there were incompatibilities in definitions, data that were not entered properly, misspelled street names, and a myriad of other conditions. While the system is conceptually capable of performing a function, the reality of performing it on a large data set with numerous other users attempting to use the same resources is often quite different.

While the focus of most persons embarking on an automation project is on the technology, the lesson learned is that the organizations and persons are the critical issues. The levels of cooperation or rivalry, the ongoing turf battles, the justification of resources, the personal abilities and attitudes, and many other human factors become the most important issues in the success of an MPLIS automation project. The nature of MPLIS is such that sharing is an important element in its success. Sharing, of course, means multiple organizational units and multiple organizational units need to cooperate. Leadership, past relationships, and the need for the automated MPLIS all contribute to cooperation and success, or the lack thereof.

REFERENCES AND ADDITIONAL READINGS

See Chapter 21.

25 DATABASE DESIGN

Nancy von Meyer

INTRODUCTION

Historically, GIS and LIS databases have been designed as stand-alone, single purpose systems. These systems focused primarily on graphic display of data and served individual functions or data "layers", such as parcel mapping,. soils mapping, or graphic display of utility infrastructure networks. This approach, with a limited view of automation, was the standard procedure for most data processing twenty-five years ago, due to the limitations of technology. The resultant constraints that single purpose systems put on system development was the impetus for the development of database management software and information engineering methodology. Because this software and methodology are now available, technology is no longer a constraint, rather systems design has now moved to the forefront as a formidable hurdle. (As noted in earlier chapters, institutional arrangements also continue to be a major hurdle in many governmental environments.) The key to maximizing the efficiency and effectiveness of MPLIS systems is to take full advantage of the available tools and methods to design systems that are truly multipurpose.

In the past, the "build it as you need it; design it as you build it" approach seemed to be the expedient way to proceed. However, this approach created long-term problems for adding applications or incorporating LIS data into other automated data processing systems. That is, this approach is analogous to building a large house by constructing one room at a time and designing each room as construction progresses. Inefficiencies result both in the design and build process, as well as when using the resultant product or system.

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The real power of GIS and LIS systems is the link geography provides among an organization's processes, data, and technology. However, to take advantage of this power, the design of the system components and databases must be completed before the system is built (Williamson and Hunter, 1989, p.14).

An MPLIS needs to be recognized as one part of a larger information system in an organization. The geographic databases are an integral part of nearly all information system data and functions. For example, the parcel mapping application depends on both land use and landownership data; and the erosion control systems require land use, ownership, and soils data. Land records data are the basis for most local government interaction with citizens, whether related to land development, environmental planning, or taxes. An organization-wide approach to system and database design identifies each of these relationships, and helps create new opportunities for cooperation before the MPLIS system is implemented. This broad design approach also results in lower maintenance costs as the system matures, thus increasing the long-term viability of the investment in an MPLIS.

This Chapter presents an overview of GIS and LIS database design, using the principles of information engineering, to ensure a consistent, comprehensive approach to system design.

INFORMATION ENGINEERING

Information engineering provides a structured approach to system design by integrating the organization's mission and goals with the processes and data that are used to execute them. Martin and Finkelstein have been credited with developing the first information engineering principles at IBM in the 1970's. (Martin, 1989; Finkelstein, 1989).

Information engineering describes technologies, processes, data, and organizational structures in a systematic manner. It shows an organization how information is created, used, and flows. This design methodology prevents building applications in isolated systems. It helps the organization change the way it processes information in response to new technological capabilities.

The four basic components that are included in the information engineering methodology are: data, technology, processes or functions, and organizations. Data are the most widely recognized and documented component. Data modeling in information engineering describes how the bits of information are defined and structured so they can be applied in a meaningful way. Technology is also widely documented. Technology includes things like software, hardware, and system protocols. Processes or functions describe tasks and how information and technology are used to accomplish organizational goals. Organizations encompass the rules for assigning responsibilities and authorities for the people who perform tasks and use technology. These include things like who does which tasks, what data they need, and what are the attendant skill requirements.

One approach to prioritizing the four information engineering components is to look at their life cycles. Technology is probably the shortest life cycle, ranging from eighteen months to two years. As examples, software upgrades occur yearly and new inventions and innovations emerge almost daily. Processes or functions also have a relatively short life cycle. In public agencies the mandates that drive activities, and hence the activities themselves, can turn on each election or legislative cycle. Organizational life cycles are generally measured in terms of individual careers. Historically individual careers lasted thirty to forty years. More recently career cycles are five to fifteen years. Data have the longest life cycle of the four components. For example, in land records applications it is common to find data that are one to two hundred years old. Data are often characterized as corporate information resources. This long life cycle means that data design is one of the most critical designs in a GIS.

DATABASE DESIGN PHASES

Database design occurs in phases. It moves generally from broad and strategic views to detailed system-by-system specifications and designs. There are three distinct design phases: conceptual, logical, and physical. Figure 25-1 illustrates the relationships of the three phases of database design as analogous with engineering and architectural planning for a building.

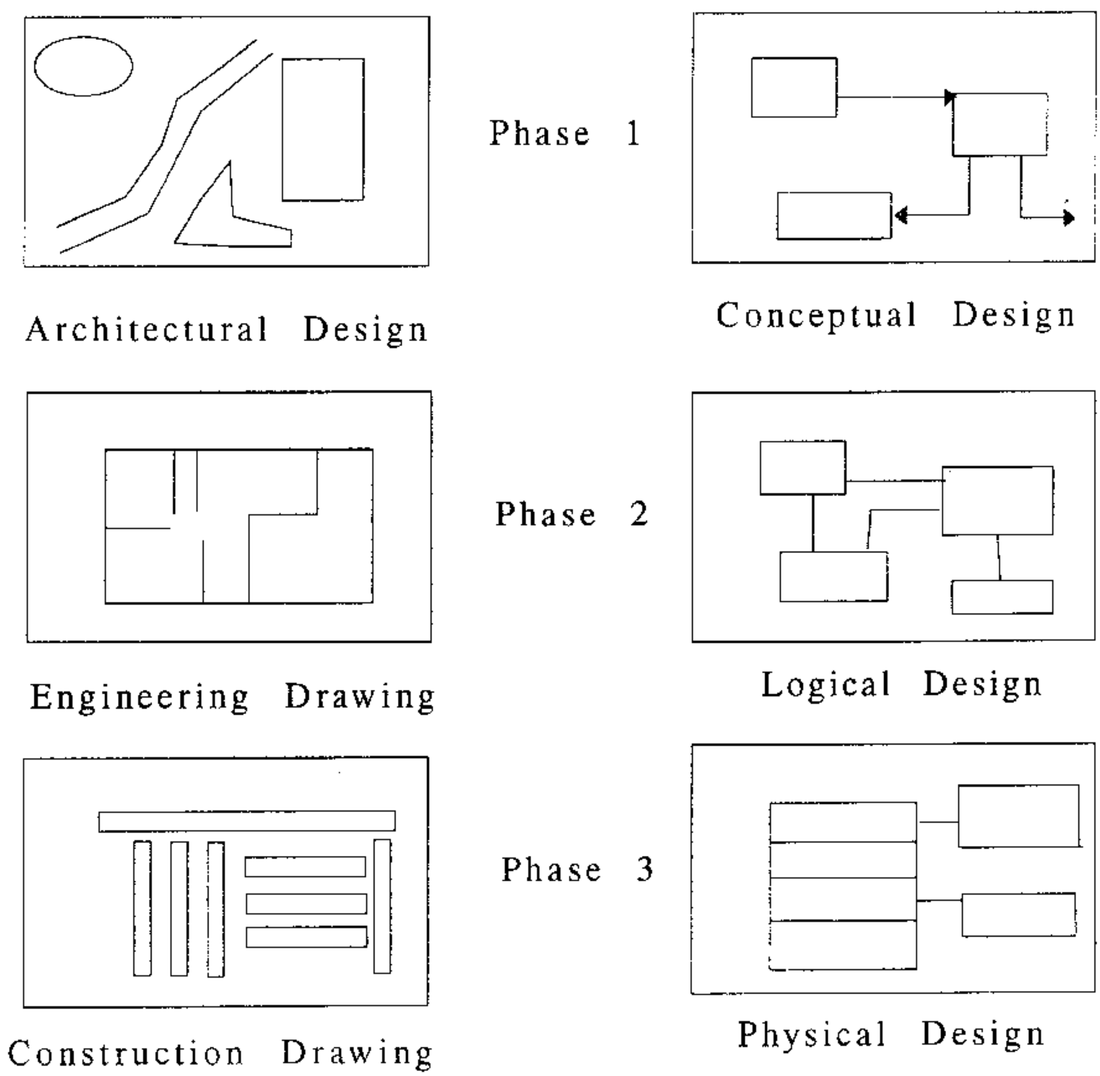

Figure 25-1: Phases of Database Design

CONCEPTUAL DESIGN

The conceptual database design is similar to an architectural design, as shown in Figure 25-1. An architectural design shows the landscape, vegetation, building sites, and general building layout. The conceptual database design identifies the scope, purpose, scale, and functionality of the system in general terms. It identifies which data should be grouped into which databases, the relationships among these databases, and the relationships of databases to functions and processes of the organization.

The conceptual design begins with the development of an **enterprise data model**. An enterprize data model describes departments and structure of an organization, the functions and processes involved in their work, and the data sets that support that work. For example, if a local government is designing a land records system, the enterprise data model describes how a land record is created, how it is used, who updates, and when it is retired. Table 25-1, from Ventura, 1991, is a list of some of the people who may be involved in the initial stages of development of a land records system enterprise data model to identify the information content and flow.

The enterprise data model does not require the details or the definitions of each data element. Figure 25-2 shows a simplified enterprise model for a land records-related system in a local government. The enterprise data model shows that land recordation is more involved than creating a map of the parcel. It is a public record of the rights and interests in land. Many people help create that record and many people use both the text and graphic information. It also shows some of the potential pathways for data sharing among various data systems.

County and municipal office or functions
- taxation/assessment
  - real property lister
  - abstractor
  - assessor
  - clerk
- register of deeds
- landmarks commission/historical society
- surveyor
- zoning administrator/zoning inspector
- public works
  - water
  - sewer
  - gas and electric
  - transportation
  - storm drainage
  - engineering
  - waste management
- conservation
  - land conservation department
  - agricultural extension services
  - county forest manager
- planning
- community development
- recreation/parks
- building inspection/permits and licenses
- public safety (emergency services, fire, police, rescue)
- data processing
- sanitarian/health officer

State Departments (including regional offices)
- Natural Resources
- Transportation
- Revenue
- Administration
- Agriculture, Trade and Consumer Protection
- Industry, Labor, and Human Relations
- Justice
- Development
- University of Wisconsin
  - system campuses
  - State Cartographer
  - Geological and Natural History Survey

Regional and special districts
- registrar of voters
- school districts
- sewerage districts
- regional planning commissions
- lake districts
- watershed associations

Federal
- Soil Conservation Service (Agriculture)
- Agricultural Stabilization and Conservation Service (Agriculture)
- US Forest Service (Agriculture)
- Environmental Protection Agency
- Geological Survey (Interior)
- Fish and Wildlife Service (Interior)
- Bureau of Land Management (Interior)
- Federal Emergency Management Agency
- Bureau of Census (Commerce)
- National Geodetic Survey (Commerce)

Private
- boards of realtors
- title insurance companies
- timber companies and other land holders
- consulting engineering firms
  - surveying and mapping
  - photogrammetry
  - GIS
- appraisers
- professional organizations (e.g., Wisconsin Surveyors associations, WLIA)
- land-holding conservation organizations (e.g., Nature Conservancy)
- utilities
  - gas
  - electric
  - water
  - cable television
  - telephone
  - digger's hotline services

Table 25-1: Local Land Records Users
Source: Ventura, 1991

Building the enterprise data model provides information to system designers and helps to educate the organization about information and its flow. By documenting the organizational data needs and data movements in the enterprise data model, it is possible to mitigate the problems of stand-alone system design. The model also provides an opportunity to re-engineer or reshape the way information flows through the organization. Once people see the interconnections and the dependencies of information, they more fully understand the needs for and benefits of data sharing.

LOGICAL DESIGN

The logical design is an equivalent of an engineering drawing, shown in Figure 25-1. An engineering drawing specifies the materials of construction, beam sizes and placement, and structural design elements of the building. It defines room sizes and dimensions. The logical design contains detailed data relationships and definitions. In the logical data design each piece of information that an organization is required to manage is defined and related to other information. An organization needs the logical data design to serve as a reference for all application and database design efforts (Parr, 1992, page 11). The logical data model is a basic reference for automation. It reduces complex data to an understandable and implementable basis.

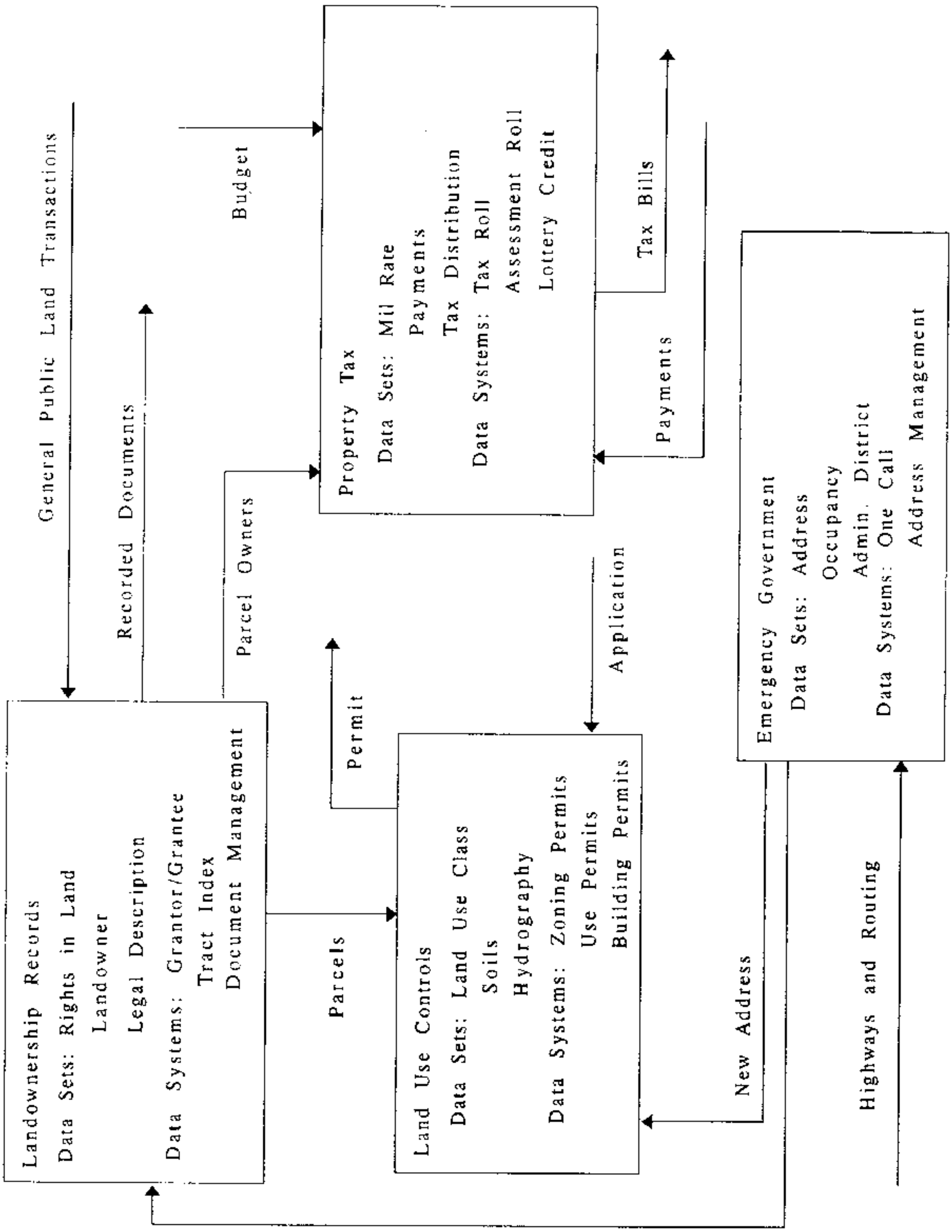

Figure 25-2: Sample Enterprise Model of Land Records for a Local Government

The logical design begins with an **entity-relationship diagram**. This diagram contains the objects or entities that are contained in the database system and the relations or associations between entities.

A data entity is any object about which the organization chooses to collect data. Attributes are additional information about the entity. Entities and their attributes are defined in a data dictionary. For example, a data dictionary would define the entity "administrative district" and would contain the list of attributes or information about administrative districts that need to be stored in a database.

In entity relationship diagrams, there are three types of associations: one-to-one, one-to-many, and many-to-many. See Figure 25-3 for examples of each type of association. One method of diagramming entity-relationships is illustrated in Figure 25-3. The "crow's foot" symbol is a many relationship and single lines are a one or single relationship.

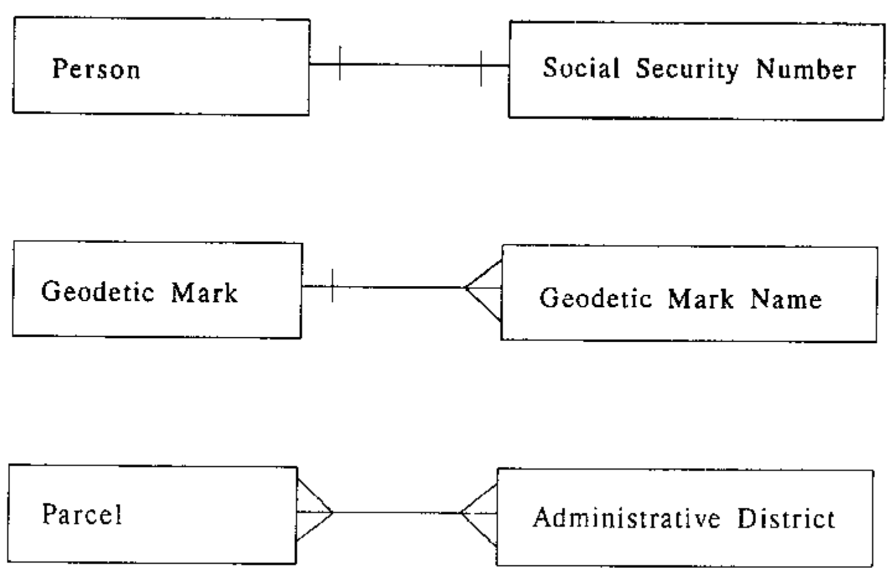

Figure 25-3: Entity Relationship Diagraming Examples

A one-to-one association (1:1) means that at a point in time a given value of A has one and only one value of B. For example, one person has one social security number. The person and their social security number is a one-to-one association. Most one-to-one associations are described as a unique attribute of an entity.

One-to-many association (1:m) means that item A could have an arbitrary number of items C associated with it. For example, a parcel of land could have many landowners with each owner having a specified percentage of ownership rights. In this case the parcel of land has a one-to-many relationship with landowners. Another example, shown in Figure 25-3, is a geodetic survey marker (geodetic mark) and the station or mark name or identifier. Geodetic markers often have several identifiers or names. This is a one-to-many relationship.

Many-to-many associations (m:m) occur when at a point in time a given value is associated with many other values and the converse is also true. For example one parcel can be located in many administrative districts such as fire, police, school, and emergency response. Conversely, one administrative district is composed of many parcels. This is shown in Figure 25-3.

Relationships among entities are shown on an **entity-relationship diagram**. Entity-relationship diagrams were introduced as a design tool for information systems by Chen, 1976. There are many different styles for entity-relationship diagrams, but they all have a means to illustrate entities, their attributes, and the associations among entities.

The purpose of the entity-relationship diagram is to describe all data an organization collects or uses in an organized manner. Each piece of data or individual data element should be listed in one place on the diagram. For example, there should be one entity for address where all address information for a jurisdiction is defined. If another entity, such as a parcel, needs to be related to address, then an association is constructed between the two. Having each data element defined and shown once is called a normalized data model.

The logical design should eliminate duplicate data definitions. The process of removing duplicate or redundant information is called normalization. There are five levels of normalization with each higher level removing another type of duplication. A typical design strives for the third level of normalization or the third normal form.

The relationship between data and processes in the logical design is shown in a process to data matrix. This matrix is often termed the CRUD Matrix because it illustrates which processes or functions create, read, update, or delete data. Figure 25-4 illustrates a sample land records matrix for a property tax office.

Example Property Tax Functions

Data	new record	update owner	new owner	add parcel	parcel split	parcel combine	update address	compute mil rate	update roll	produce new roll	lottery credit	first payment	second payment	delinquent record
legal descrip	R			R	R	R								
grantor	D	D												
grantee		R	R	R	R									
purchase amt.									R					
assessment								R	R					
budget								C	C		R			
tax owed									C	C	C	C	C	C
interest owed									C	C	C	C	C	C
change of addr							U							

Figure 25-4: Example Create, Read, Update, and Delete Matrix

PHYSICAL DESIGN

The physical design is equivalent to construction drawings, shown in Figure 25-1. Construction drawings show the builders exactly which pieces fit together, what cuts need to be made, and fastener details. These are the plans that are used to order lumber and materials. Likewise the physical data design describes in detail how data are implemented in a system and the specific connections and programs necessary for all data linkages and joins.

In the physical design the ideal representation of an organization's data is restructured to conform to the requirements of specific hardware and software. This design process is called denormalization which means that some data redundancy is reintroduced into the data to optimize system performance. For example in a logical model administrative districts and parcels are modeled separately and shown as two separate entities. In a physical implementation administrative districts and parcels may be combined in one computer table with each parcel having a list of its associated administrative districts. This creates duplicate data since the administrative districts are repeated for each parcel, but enhances parcel retrieval time by eliminating table join and search time.

It may seem that the physical design unravels the work from the logical design, but the denormalization process is necessary for optimum technology performance and should be done in a manner that assures data integrity. In this case data integrity means that if an attribute value is changed in one place, such as in a table of values, that all other occurrences of that attribute value for that record also change. This means that one of the data maintenance requirements is to maintain data integrity. There is also a balance between storing data or generating data. If some information is derived from combinations of data, the system can either regenerate the information each time it is needed or store the information after it is generated. These decisions are system or technology dependent and are made to optimize the system performance for particular applications.

DATA DESIGN SUMMARY

A summary of the three phases of database design and their relationship to level of detail, dependance on technology, and normalization are in Figure 25-5. In the conceptual phase the data design defines major data systems and their relationships. There is no attempt to define technology or system requirements for data. In the logical level the data systems are described in detail. The logical design strives to be technology independent and eliminate redundant data definitions. In the physical design, the logical model is implemented on a specific system and technology. Some data duplication is added to enhance system performance.

	Level of Detail	Normalization	Technology Dependence
Conceptual	low	medium	low
Logical	medium	high	medium
Physical	high	medium	high

Figure 25-5: Database Design Phases Summary

SPATIAL DATA DESIGN

The data design described above includes the general phases of design that apply to text or written information and spatial or map data. There are some special considerations for spatial design, particularly at the physical data design phase. This section describes some of these considerations for spatial data design.

SPATIAL DATA STRUCTURES

There are two basic forms of spatial data representation, vector and raster. These are sometimes called data structures or data models, but they are forms for managing spatial data in a computer. A logical data model for spatial information such as parcel maps or utility networks, can be represented in either spatial data form.

The vector form is a combination of points, lines, and polygons. These are the computerized representation of the objects typically used in manual mapping. Points are the ends of lines or places on a map that represent entities like manholes, utility poles, or survey control stations. Lines connect points and may form the boundaries of areas. Polygons are the areas.

The raster form is a combination of rectangular or square cells. Each cell is called a grid cell or a pixel. Computer screens, satellite images, and electrostatic plotters all use raster forms to display data. Raster forms use color or gray tones for cells. Cells are located by a column and row system to represent their relative location in a file. Typically another file or a file header describes the geographic location of the origin of the row-column system.

An example of these two spatial forms is shown in Figure 25-6. In the vector map on the left, representation areas are delineated with lines and values for the areas or polygons are shown on the map. In the raster representation of this same information on the right, grid cells are overlaid on the vector representation and each cell within the grid is assigned the attribute value that the cell most nearly fills.

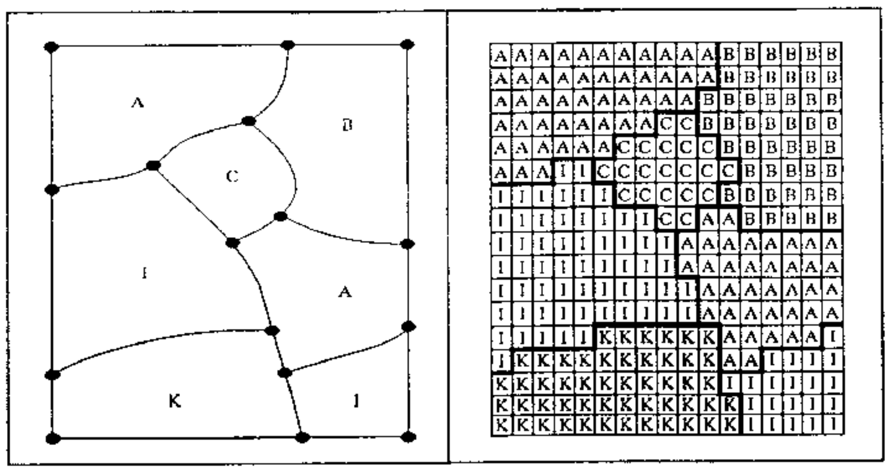

Figure 25-6: Vector and Raster Representations

The choice between vector and raster data forms usually depends on the application. For example, images or photographs displayed behind a map are typically managed in a raster form. Parcel maps and networks are managed more commonly in a vector form. In the past the combination and overlay of these two forms was a very complicated process. Modern GIS packages now handle this operation much easier. Likewise, the conversion between the two forms used to be fairly complex, but is now a routine part of a GIS package.

What is important about these two forms is their affect on the resolution and display of the spatial data in the GIS. A raster form's preciseness is defined by the size of the grid cell. The smaller the grid cell the higher the resolution. The price for this resolution is storage size. It takes much more memory and computer horsepower to store and manage higher resolution raster images than lower resolution images. The same is generally true for vector data, higher resolution vector data will have more lines and more storage requirements than lower resolution data.

There are many excellent references that discuss the differences between raster and vector forms. These are included in the list of references at the end of this chapter and can be found in other Chapters of this Guidebook (e.g., see Chapter 22).

Another type of spatial data structure is called topology. Topology is a branch of mathematics that describes how things are related to one another. Topology contains all the information about spatial data that is independent of data location. As examples, an object's shape, its relative location, and its connectivity to other objects are topologic relationships. Topology is generally the difference between computer aided mapping and a GIS. For example, a computer aided mapping software package may manage raster and vector data together in one environment, but may not be able to support topologic relations such as nearest neighbor or adjacency.

All geographic information systems use topologic data structure. This is the structure that allows a GIS to do overlays, connectivity, network analysis, and buffering.

SCALE

The implementation of a data design for spatial information has to specify the scale aspects of data capture and use. Scale related information determines how much of the spatial information is shown. For example a system for representing highway information may show one line for the road, it may show a line for each lane, or it may show the curb-to-curb geometry of the road. Typically the more detail that is shown in the spatial data display, the more detail that is needed in the logical model.

Figure 25-7 shows three maps of a portion of Iowa County, Wisconsin. Each map shows more detail than the previous one. The amount of detail in terms of attributes about the highways increases as the level of detail increases. This means that the logical data design will be more detailed to support the more detailed maps.

Highway Representation 1	**State Highway Map**
Accuracy	**1/2 Mile**
Precision	**Cartographically placed**
Resolution	**Federal, State, and County Roads**
Extent	**Entire State**

Attributes	Road Name	Number of Lanes	Administration	Surface Type
Record 1	18-151	4	State	Concrete
Record 2	78	2	State	Asphalt
Record 3	39	2	State	Asphalt
Record 4	K	2	Iowa Co.	Asphalt
Record 5	F	2	Iowa Co.	Asphalt
Record 6	A	2	Dane Co.	Asphalt

Figure 25-7: Map 1 of 3 for Iowa County, Wisconsin
State Highway Map

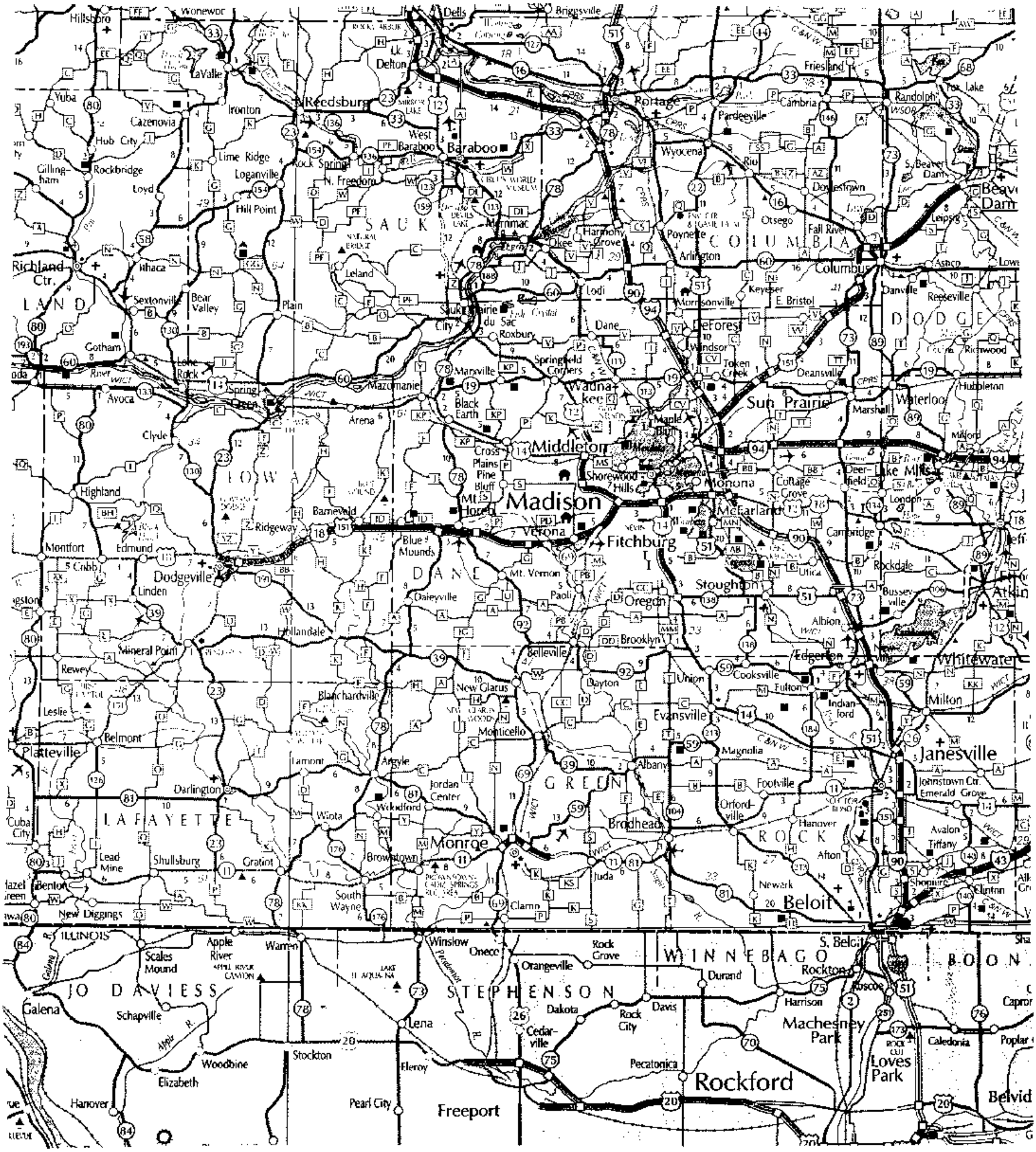

Figure 25-7: Map 1 of 3 for Iowa County, Wisconsin State Highway Map

Highway Representation 2	**State Highway Map**
Accuracy	**1/10 Mile**
Precision	**Generalized from Aerial Photography**
Resolution	**Federal, State, County, and Township Roads**
Extent	**6 mile by 6 mile area**

Attributes	Road Name	Number of Lanes	Administration	Surface Type	Right of Way Width	Shoulder Type
Record 1	F	2	Iowa County	Asphalt	4 rods	3' gravel
Record 2	K	2	Iowa County	Asphalt	4 rods	3' gravel
Record 3	H	2	Iowa County	Asphalt	3 rods	2' gravel
Record 4	Mounds View	2	Brigham Township	Asphalt	2 rods	grass
Record 5	Reilly Road	1.5	Brigham Township	Gravel	2 rods	grass
Record 6	Oimoen Road	1.5	Brigham Township	Gravel	2 rods	grass

Figure 25-7: Map 2 of 3 for Iowa County, Wisconsin County Road Map

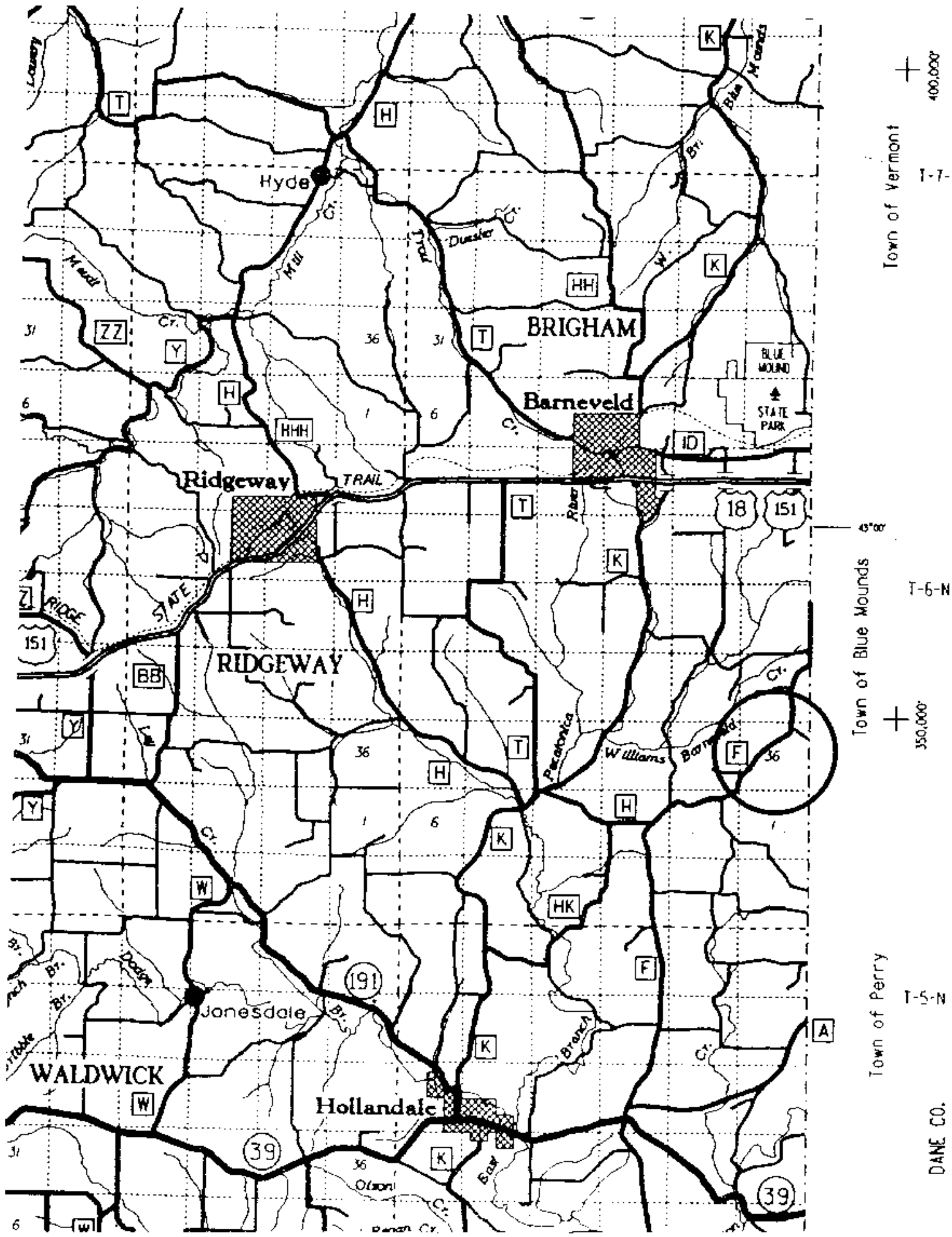

Figure 25-7: Map 2 of 3 for Iowa County, Wisconsin
County Road Map

Highway Representation 3	**Parcel Survey**
Accuracy	**0.05 Feet**
Precision	**3rd-Order Traverse Survey**
Resolution	**Rights in Land Features**
Extent	**One Parcel**

Attribute	Record 1	Record 2
Road Name	Oimoen Road	Ingress/Egress
Right of Way Width	66 feet	50 feet
Travelled Way Width	33 feet	25 feet
Administration	Brigham Township	Landowner
Reversion Rights	Adjoining Owners	Easement Grantor
Document Reference	County Survey	Plat of Survey #423

Figure 25-7: Map 3 of 3 for Iowa County, Wisconsin
Parcel Survey

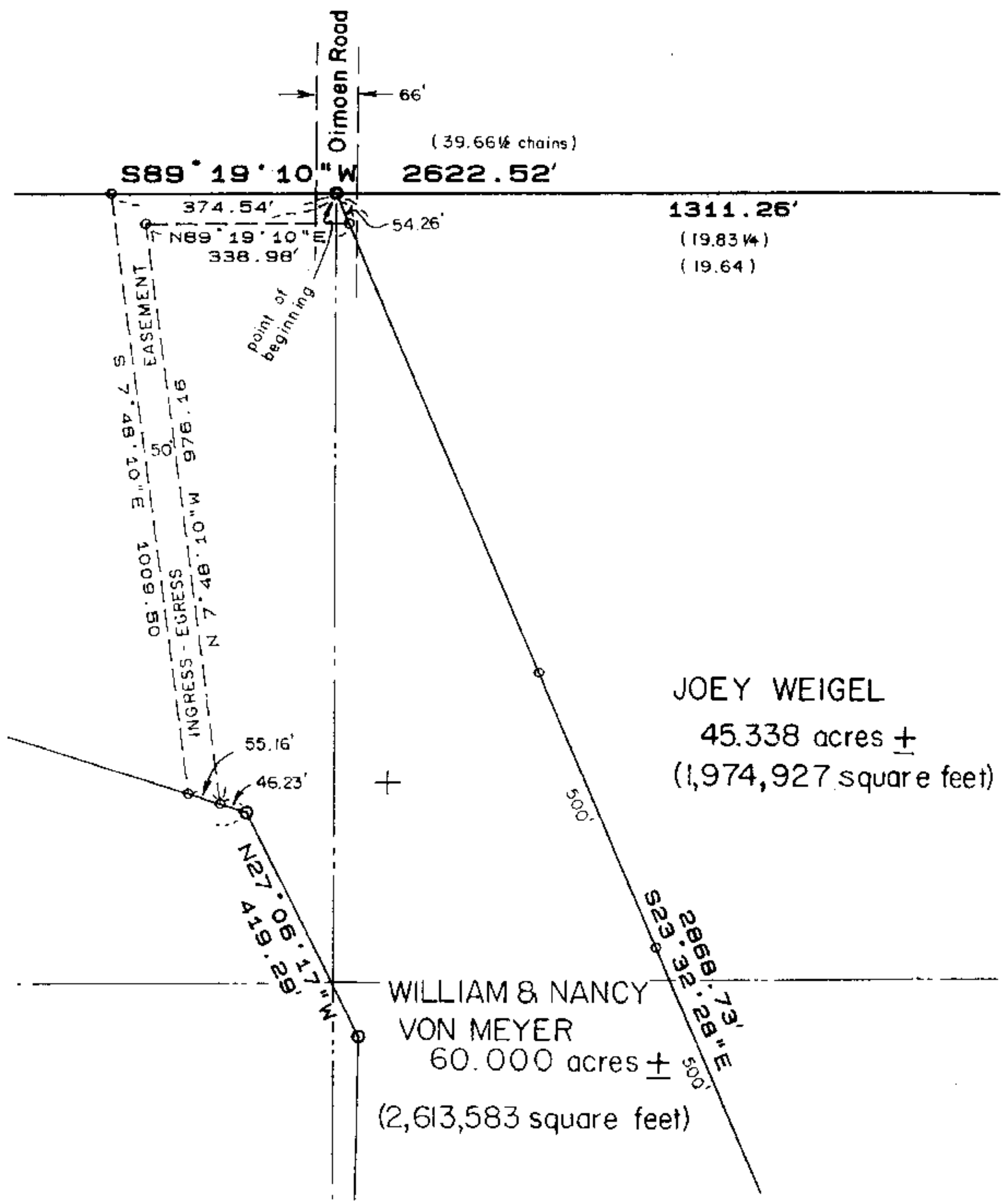

Figure 25-7: Map 3 of 3 for Iowa County, Wisconsin Parcel Survey

There are four aspects of scale that must be considered. These are related to one another, and are used to help determine the level of detail needed in both the logical data design and in the presentation of the spatial data.

Precision - A measure of the uniformity or "reproducibility" of the result of a set of measurements. Precision relates to the quality of the operation by which a result is obtained. For example, precision describes the methods or processes that are followed and how well those process will reproduce the same result.

Accuracy - The degree of conformity of a product with a standard or accepted value. Accuracy relates to the quality of a result or the data obtained from a process. After data have been collected the quality of the result is often expressed as accuracy.

Resolution - The minimum distance between two adjacent features or the minimum size or importance of a feature that is shown on a map, image, or drawing. A measure of the completeness of theme representation. Resolution can be shown in three ways: (1) line and point graphics which is the mapped representation of features, (2) annotation or other related text information associated with features, or (3) symbology which may be explained in map legends or description legends.

Extent - The geographic area covered by a single map or drawing or by a collection of a similar set or series of maps and drawings.

SPATIAL DATA DESIGN SUMMARY

Geography integrates data in a geographic information system design and implementation. As noted earlier the real power of GIS is the link geography provides among an organization's processes, data, and technology. This link is the integration.

Not all spatial data are equal. The precision, accuracy, resolution, and extent describe characteristics of spatial data. As Figure 25-6 illustrates, the spatial data design for street and road information depend on the precision, accuracy, resolution, and extent of both the source data and the intended data presentation.

AN APPROACH TO DATA DESIGN

One example of a cooperative local government data design project is the University of Wisconsin - Madison coordinated project called LOCALIS. In 1990 a collection of University departments, representatives from six counties, the Environmental Systems Research Institute (ESRI), Earth Resources Data Analysis Systems (ERDAS), and International Business Machines (IBM) combined to define priority data elements for local government applications. This project is one case study of the steps involved in developing the conceptual, logical, and physical design for a geographic information system. The project description is taken from a LOCALIS data design project report (Thum et al., 1993).

The five steps defined in the LOCALIS project design process include: User Needs Assessment, Conceptual Design, GIS Data Model Selection, Physical Design, and Prototype Evaluation.

The User Needs Assessment involved county representatives in two meetings totalling three days. In these meetings the group reached a consensus on the types of data they managed, the types and form of information the public and other agencies brought to their offices, and the types and forms of the products they produced for the public and other departments. From these descriptions the LOCALIS staff prepared unified land data inventories for each county. The combined data inventory formed the enterprise data model described in Section 3 above.

The Conceptual Design involved categorizing the inventory information from the User Needs Analysis, the required representations of the information, and the relationships among the major categories of data. The conceptual design in this step is the logical design described in pages 5 through 7 above. Some of the difficulties experienced by the LOCALIS project are typical of those in any logical data design process. One example summarized by Thum etal,. 1993(page 7) is:

This (the logical design) is often not an easy task. Different staff in different Departments often have very different perceptions of the world. For example, a planner may view roadway information as the entire transportation network which influences land development and growth patterns and is a determining factor in the demographic landscape. On the other hand, an engineer may view roadway information in terms of road construction, pavement management, and traffic carrying capacity.

Another difficulty the LOCALIS encountered related to defining attributes and entities. Depending on the precision, accuracy, resolution, extent, and currency of the spatial data, an item may be an attribute or an entity. For example, to the planner the number of lanes is an attribute of an extensive road network, but to the engineer each lane is an entity with its own markings and carrying capacity. Another example is a center turn lane which may be a lane to the engineer, but not to the planner.

The GIS Data Model Selection involved selecting which spatial data structure, i.e., raster or vector, would be appropriate for each entity. It also involved selecting specific platforms for project implementation. "Selecting the right array of products requires a good understanding of internal data automation, management, and analysis needs... The Conceptual and Logical design help identify strategies for technology investments." (Thum et al., 1993, page 18). This step is the precursor to the Physical Design. That is, before the logical data design can be optimized to a particular platform, the platform requirements and operation must be known.

The Physical Design involved translating the identified user needs and logical data model to the geographic information system. In this step the naming conventions for products and files were specified. The data layers were defined and built. Attributes were added to the various layers as the system evolved. The table joins or relationships between layers, as defined in the logical model, were programmed.

The Prototype Evaluation involved verifying that data relationships in the Physical Design met the requirements in the Logical Design and that the required products could be generated. The physical design was modified and improved through the results of the Prototype Evaluation.

The five steps used in the LOCALIS project are typical of those in most data design efforts. The steps sometimes have different names or there may be more or fewer steps. The critical components are that conceptual, logical, and physical data designs need to be produced for every database design.

SUMMARY

A systematic approach to database design will result in a rigorous data system that will support geographic information systems and organization-wide data needs. The results of data design will also enable the organization to optimize their organization for efficiency and effectiveness. Particularly in these times of tight budgets and reduced public resources, database design should be considered as one more tool for re-engineering and improving an organization.

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