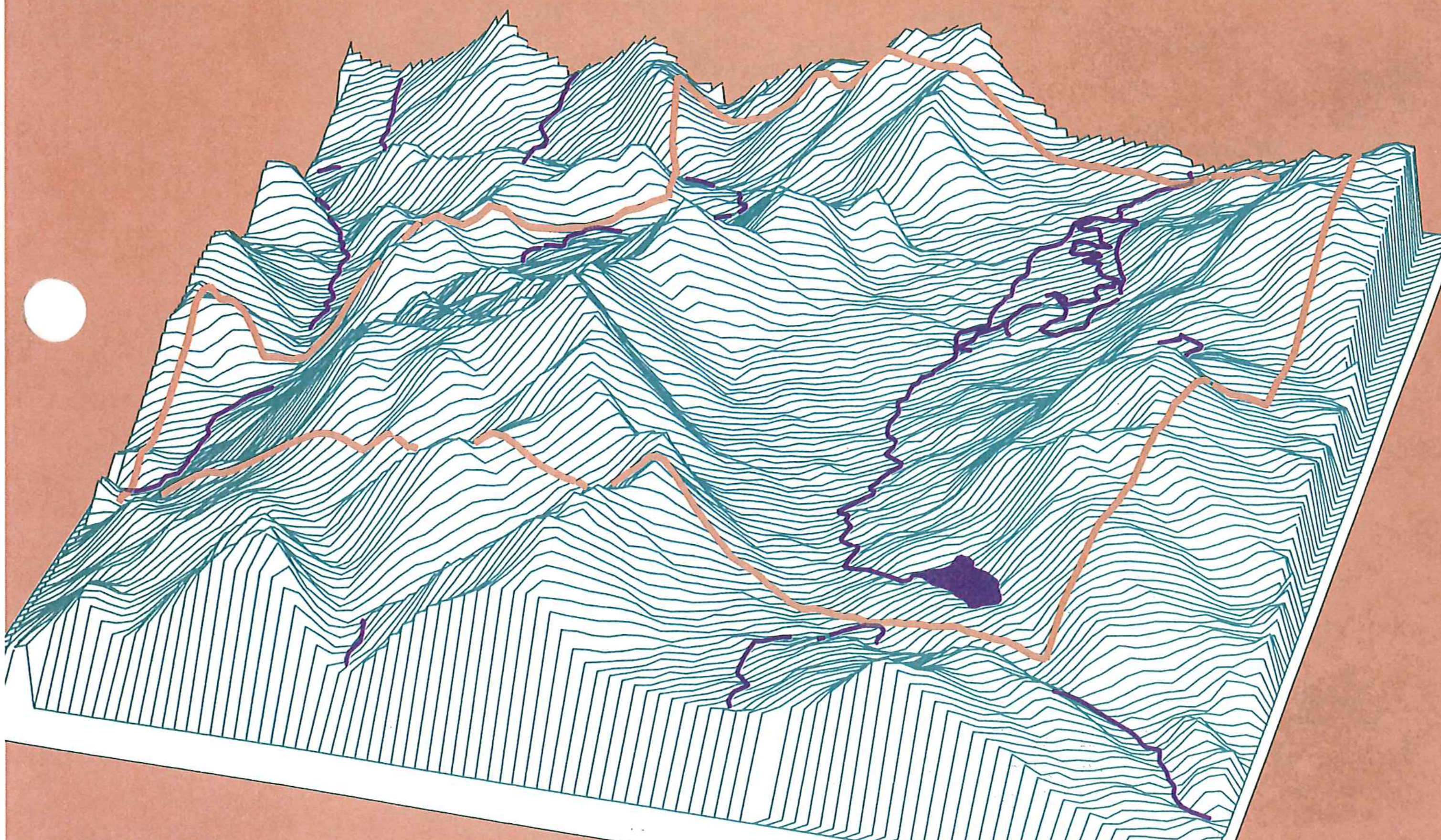
GIS *for* Vermont Communities

APPLICATIONS & CONCEPTS



Office of
Geographic
Information
Services

GIS
for Vermont Communities
Applications and Concepts

State of Vermont
Madeleine M. Kunin, Governor
Agency of Administration
Thomas Menson, Secretary
Office of Geographic Information Services
Bruce Westcott, Director

Written by: *Lenore F. Budd*
Associates in Rural Development, Inc.
Burlington, Vermont

Editing: *Star Albright, Clair Dunn, and Andy Lowe*
Associates in Rural Development, Inc.
Burlington, Vermont

Design: *Clair Dunn*
Associates in Rural Development, Inc.
Burlington, Vermont

Project Director: *David Healy*
Vermont Office of Geographic Information Services

The author gratefully acknowledges the assistance of the many individuals who reviewed and commented on the text, those who provided materials for inclusion as figures, and those who provided production assistance. These include: Bill Hegman, Scott McCormick, and Paul Dulin of ARD, Inc., Bruce Westcott, David Healy and Steven Bower of OGIS, Gary Smith and Eileen Powers of UVM, Noel Fritzinger of the Town of Weston, the staff of the RPCs especially Eric Edelstein, Jolly Sinha, Jonathan Croft, and Joseph Bongiovanni, and the planning commissions of the Towns of Burke, Brattleboro, Braintree, and Manchester.

Table of Contents

Introduction

This handbook is about the use of maps and geographic information systems (GIS) by Vermont communities. The primary emphasis is on how planning, and other activities undertaken by local government, can be facilitated by this new technology. The goal of the handbook is not to make the reader an expert on GIS or to burden one with technical details; the aim of this book is to make the reader aware of the capabilities (and limitations) of GIS and the many ways it can be used to help solve local problems.

General information on what GIS is and how it can be applied to local situations is provided in Chapters 1 - 5. Chapters 6 - 9 provide more detailed information on technical and policy issues for those who will be more directly involved with GIS activities in the community. Throughout the text an effort has been made to separate the more technical and detailed information from the balance of the text through the use of figures, tables, sections of smaller italic type, and appendices. Readers are encouraged to consult the references listed at the end of each chapter for a fuller treatment of a particular topic. Most of these sources are available from the Office of Geographic Information Services (OGIS).

In order to gain perspective on the potential utility of GIS, Chapter 1 presents a brief overview of the myriad ways in which communities use geographic information. Chapter 2 then describes in greater detail how maps and GIS can be used in support of one local government task—developing and implementing a municipal plan. In Chapter 3, GIS is defined and the underlying concepts of its structure and function are explained. The history of GIS activity in Vermont and the evolution of the various institutions involved in it are outlined in Chapter 4. Of particular interest to many Vermont communities will be Chapter 5 in which the various means of acquiring GIS capabilities and services are explained and guidance on how to choose among the various options is provided.

Because database design is crucial to the ultimate success of any GIS venture, Chapter 6 is devoted to a discussion of what information is included in a GIS database and how it is organized. Then, in Chapter 7, the actual building of the database—getting all the information into the computer—is described. Chapter 8 briefly addresses some of the management and policy issues that individuals and planning commissions should be aware of as they become involved with GIS activities. Lastly, Chapter 9 provides a review of the principles of cartography. These principles are important because maps will be the source of most of the information put into a GIS and they will be the output format most frequently requested by community officials and other GIS users.

The development of this handbook has been a cooperative effort involving ARD, Inc., OGIS, other state agencies, the regional planning commissions, communities and individual citizens. We welcome your comments, corrections, suggestions, and examples of GIS applications so that future editions of the handbook can be more useful to Vermonters.

Chapter 1 How Vermont Communities Use Geographic Information

How does your community manage information on parcel locations: owners, addresses, dimensions, acreage, zoning, and structures—information that an assessor would be interested in? In an ideal world, with optimal data management, each piece of information would be collected, stored once, distributed efficiently, and updated as necessary. Moreover, the assessor could have at hand—in a suitable format, and in one location—all the information needed to do his or her job.

The information that an assessor uses is an example of *spatial information*—information that is linked to a location on the earth. Spatial information presents greater challenges in terms of collection, storage, analysis, and updating than does data in a more conventional tabular database, such as a bank's, because information on location, as well as the data item itself, must be stored. A surprising amount of the information a community uses, both in its day-to-day operations, and in its long-term planning is spatial, or geographic, in nature. This information can be in the form of maps, paper files, or computer data bases containing text and numbers. In the next chapter we will look in detail at the geographic information requirements of the planning process. But first, let's take a look at the myriad routine operations of local government that involve information that has a spatial (locational) component.

Municipal tasks involving geographic (spatial) information:

Conduct land use planning - Planning involves the inventory and analysis of many types of spatial information (see Chapter 2).

Administer zoning by-laws - This is accomplished by determining the location of a parcel in relationship to the established zoning districts.

Review site plans - This requires relating a proposed plan to site conditions including soils, slope, groundwater, utilities, and setbacks. Additionally, surrounding land owners must be identified and their rights and concerns considered.

Review subdivisions - Reviewing subdivision plans is similar to the site review process except more is at stake because of the larger area of land affected and the greater potential impact on community facilities and services.

Permit tracking - On a quarterly or yearly basis the location of building permits issued is evaluated to determine whether growth and development conforms to the municipal plan.

Assess properties - The assessor or lister requires parcel-related information including parcel size, location, address, frontage, building size, condition, and use.

Conduct facility siting - The building committee must analyze site conditions, proximity to certain existing land uses, transportation routes, utilities, etc.

Conduct engineering design - Designing buildings and infrastructure requires detailed site information such as soils, slopes and aspect, zoning, existing utilities, and transportation.

Perform inspections - Local inspectors need to locate industries, pollution sources, land fills, etc. in relation to residential development, schools, public water supply, aquifer recharge areas, and sensitive natural areas.

Maintain infrastructure - Maintenance is facilitated when detailed information on installation, inspection, and maintenance history of bridges, culverts, sewer, and water lines can be related to precise locational information.

Generate budget - The municipal budget should include costs for infrastructure and other capital investments for one year and five year intervals. Improved record keeping regarding infrastructure should facilitate budget preparation. Capital expenses will be reduced over the long run when maintenance, personnel hiring and scheduling, and vehicle routing can be more directly related to physical conditions existing within the community.

Event reporting (crime, fire, accident) - Each event has a location as well as other characteristics that could influence personnel assignments (e.g., police beats), new facilities construction (e.g., firehouse), or re-designing transportation routes (e.g., a dangerous intersection).

Conduct dispatching (emergency vehicles) - Efficient dispatch requires quickly identifying the exact location of the emergency and finding the optimal route for emergency vehicles (fire, police) based on the road network, road conditions, traffic patterns, and speed limits.

Perform vehicle routing (school bus, snow plow) - For optimizing school bus routes and assigning school bus stops, the school board and the superintendent need to know the location of students and their ages (grade level) in relationship to the road network. For routing snowplows, information on the road network, road class, and the location of houses, subdivisions, public facilities (e.g., schools, firehouses, and hospitals), and businesses, culverts, and bridges would be helpful.

Conduct traffic analyses - Traffic analysis requires information on where vehicles are coming from, where they are going, and how many pass a certain location during a given time. Other inputs include lane widths, locations of intersections, traffic signals, cross walks, curb cuts, and parking spaces. This is a prime example of a "what is where, when?" question.

Create street addresses - As new buildings and subdivisions are created, street addresses must be assigned. These new addresses should be linked to other parcel information such as the grand list and to the road network and utilities.

Provide legal notification - Certain kinds of hearings and applications (e.g., variance applications) require that abutters or land owners within a certain radius of the affected parcel be notified.

Disseminate public information - Community government must respond to public inquiries. The town clerk and other staff answer, or find the maps to help answer, many parcel and zoning related questions. Local government must also create and manage mailing lists. This includes tax and water bills and requires that an up-to-date mailing list of property owners be matched with the assessor's files and water meter readings.

Acquire and dispose of property - Decisions regarding condemnation, foreclosure, and right-of-way acquisition require information on roads, buildings, land use, zoning, and ownership of neighboring properties.

Because each of these tasks involves information that is tied to a location, there is potential for a geographic information system (GIS)—a computer system that stores, analyzes, and displays spatial information—to expedite it. At the present time, however, most Vermont communities take on these tasks armed only with a base map (Figure 1-1). It may or may not be current and it may or may not be accessible for frequent consultation by local committees, commissions, and the general public. What we all would like to have is instant access to relevant information. A system being developed by the Vermont Office of Geographic Information Services (OGIS) provides an excellent example of what is possible using GIS technology (Figure 1-2). This handbook should help you understand what is involved—the capabilities and limitations of the available technology, the concepts underlying it, and how to determine what is an appropriate level of involvement for your community.

Summary

- Spatial information is information that is linked to a specific location on the earth.
- Communities routinely use a great deal of spatial information.
- GIS technology is a new tool available to assist communities in storing, analyzing, and displaying spatial information.

References

Dangermond, J. and C. Freedman. 1984. Findings regarding a conceptual model of a municipal database and implications for software design in *GIS for Resource Management: A Compendium*, pp. 100-124. Edited by W.J. Ripple. American Society of Photogrammetry and Remote Sensing and American Congress on Survey and Mapping. Little Falls, VA.

Figure 1-2. A view of the Vermont GIS Browse System being developed by the Office of Geographic Information Services.

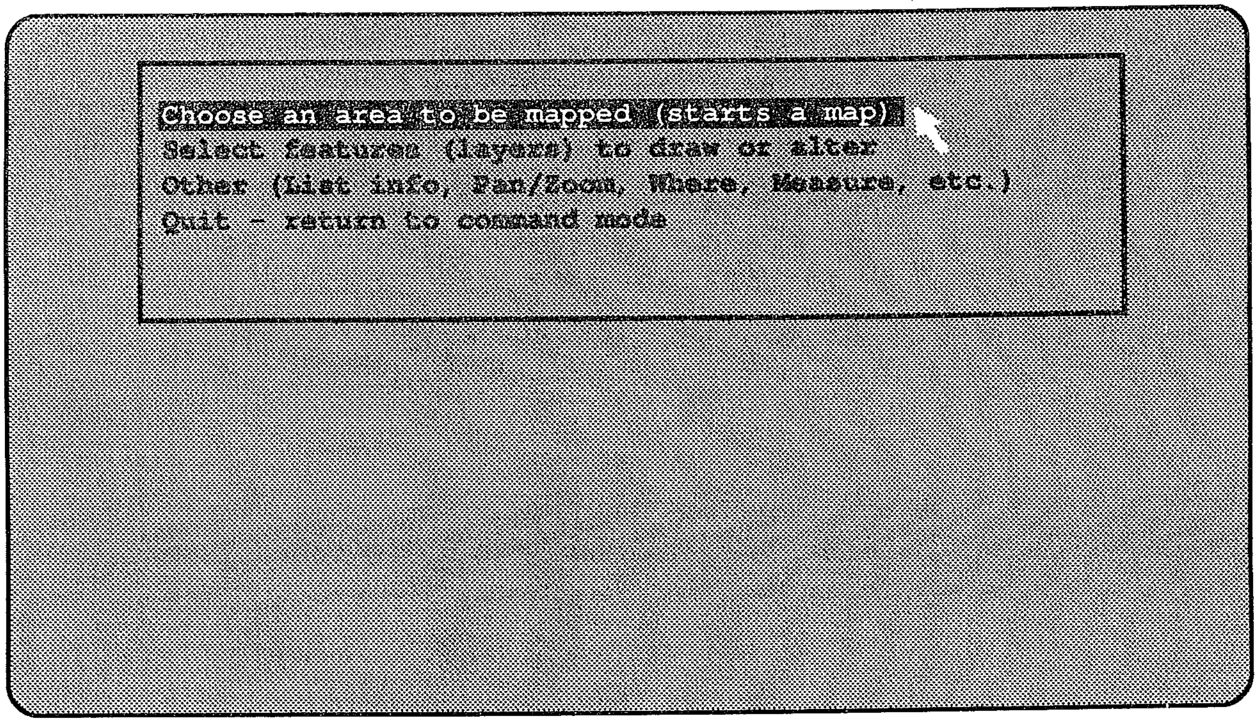


Figure 1-2A. Form the menu that appears on the computer screen, the user has selected the option: "Choose an area to be mapped."

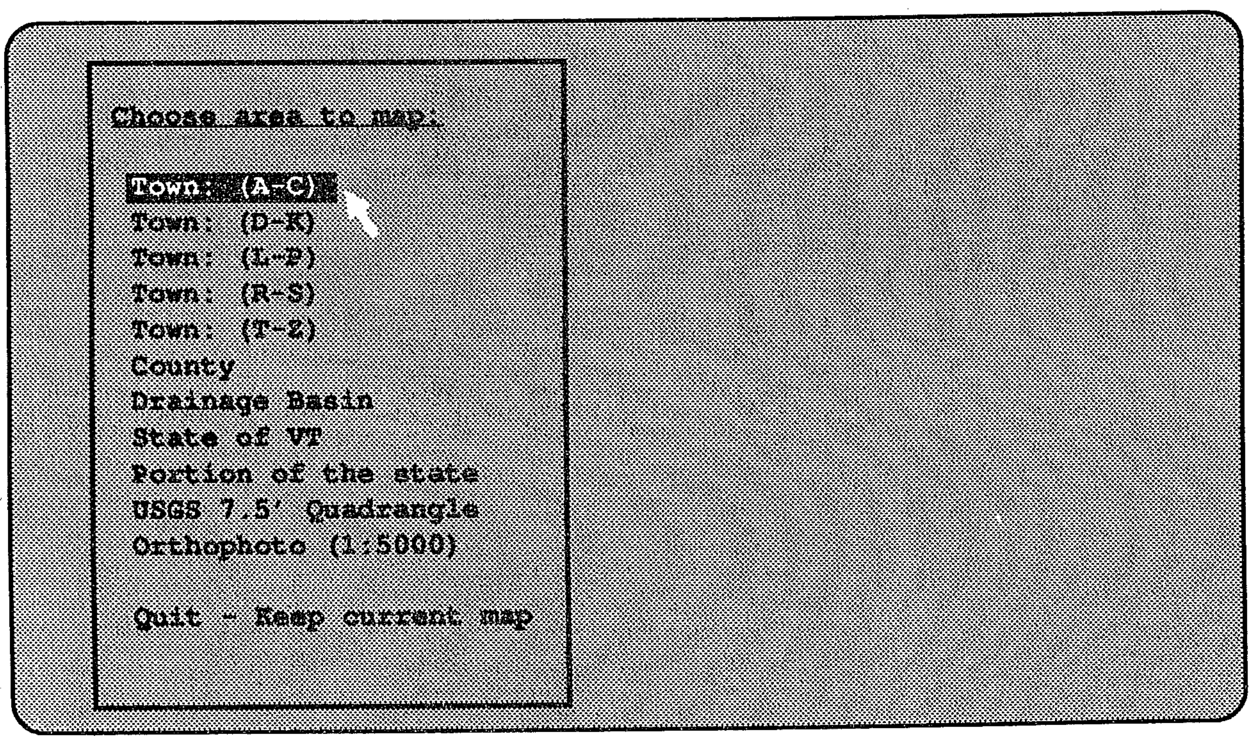


Figure 1-2B. From the next menu, the user has selected a town that begins with "A," "B," or "C."

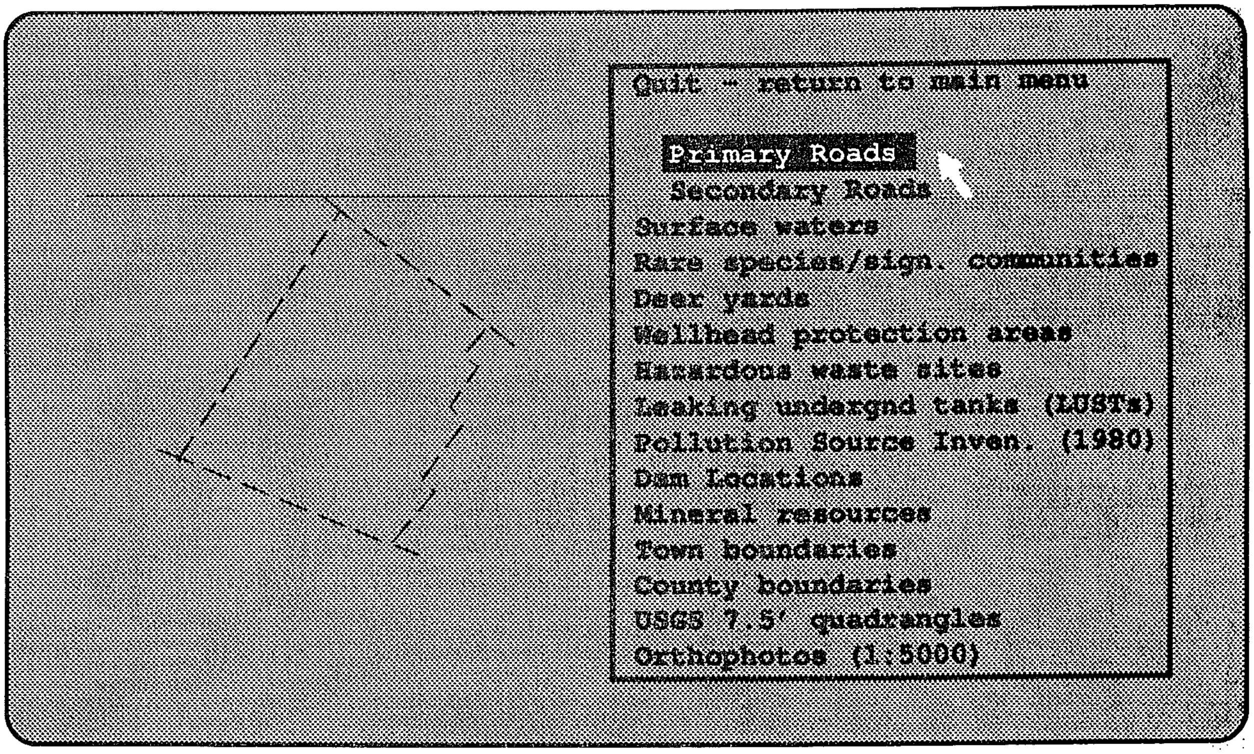


Figure 1-2C. After selecting the town from an intervening menu (not shown here), the town boundaries appear on the screen. A menu prompts the user to select the desired features.

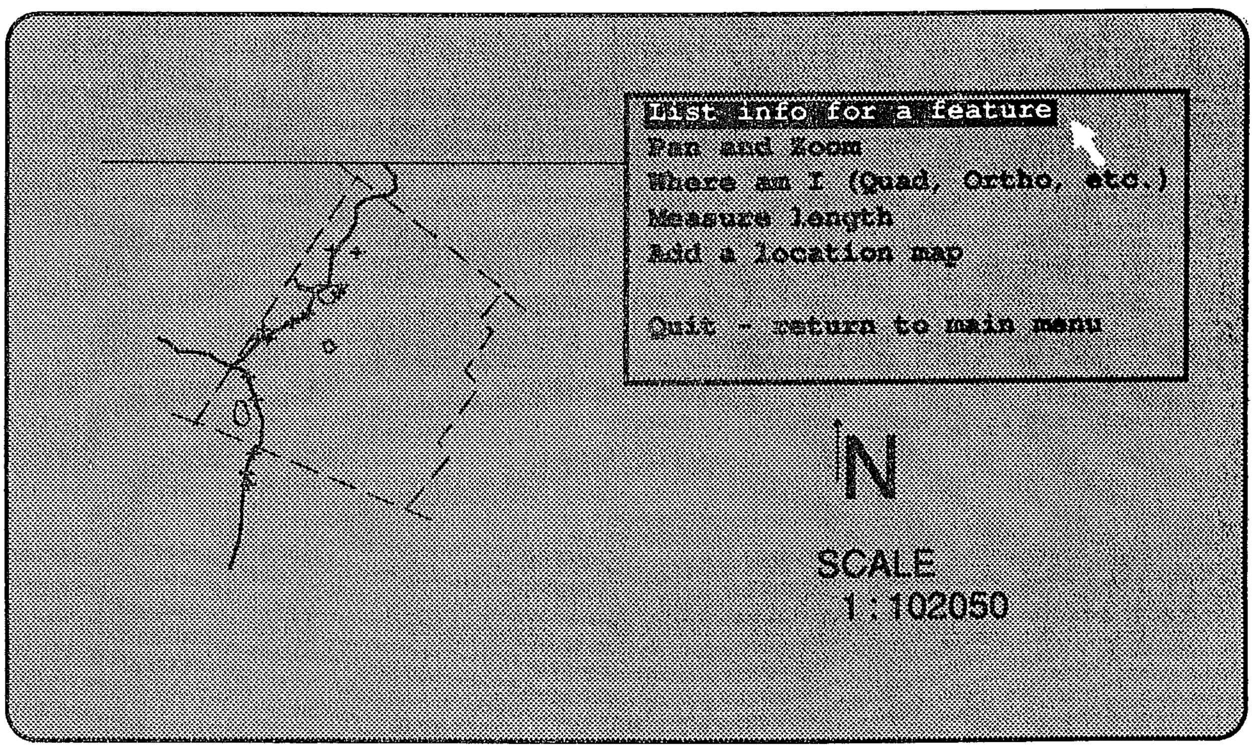


Figure 1-2D. Primary roads, wellhead protection areas, and pollution sources have been selected by the user and appear on the screen. The user is about to request attribute information for some of these features.

Chapter 2 The Role of Maps in Planning

Maps are the source of most of the geographic information needed to accomplish the tasks enumerated in Chapter 1. Because the planning process relies so heavily on mapping and the analysis of geographic data, both local and regional plans will benefit significantly from a geographic information system's (GIS) mapping, inventory, and analysis capabilities. In this chapter we will briefly review the planning process to demonstrate why this is so.

Maps and the Planning Process

Our discussion of the contributions of GIS to the planning process will follow the ideal planning process as described in the *Planning Manual for Vermont Municipalities*. An individual community's efforts to develop a municipal plan may vary considerably from this ideal due to the realities of budget, timeframe, and personnel, but the model is useful for illustrating the many roles GIS can play. The reader is encouraged to consult the manual for a full discussion of the details and terminology of municipal planning. As described in the manual there are eight steps to developing and implementing a municipal plan:

- develop municipal goals and objectives,
- collect background information,
- evaluate and analyze information,
- identify community needs and options for the future,
- develop municipal plan,
- develop implementation program,
- implement plan, and
- update plan.

1 Develop municipal goals and objectives

This initial step involves a great deal of public input and will guide the remaining steps. It will determine what background information should be collected and how it should be analyzed. In VSA Chapter 117, state law provides a set of planning goals which individual communities may or may not decide to adopt along with their own goals (Table 2-1). Some general procedural goals that GIS can facilitate are:

- coordinated, comprehensive planning - by taking advantage of many types of standardized digital data "layers"

Table 2-1. Vermont Planning Goals — May, 1990

(1) *To plan development so as to maintain the historic settlement pattern of compact village and urban centers separated by rural countryside.*

- (A) Intensive residential development should be encouraged primarily in areas related to community centers, and strip development along highways should be discouraged.
- (B) Economic growth should be encouraged in locally designated growth areas, or employed to revitalize existing village and urban centers, or both.
- (C) Public investments, including the construction or expansion of infrastructure, should reinforce the general character and planned growth patterns of the area.

(2) *To provide a strong and diverse economy that provides satisfying and rewarding job opportunities and that maintains high environmental standards, and to expand economic opportunities in areas with high unemployment or low per capita incomes.*

(3) *To broaden access to education and vocational training opportunities sufficient to ensure the full realization of the abilities of all Vermonters.*

(4) *To provide for safe, convenient, economic, and energy efficient transportation systems that respect the integrity of the natural environment, including public transit options and paths for pedestrians and bicyclers.*

- (A) Highway, air, rail, and other means of transportation should be mutually supportive, balanced, and integrated.

(5) *To identify, protect, and preserve important natural and historic features of the Vermont landscape, including:*

- (A) significant natural and fragile areas:
- (B) outstanding water resources, including lakes, rivers, aquifers, shorelands and wetlands;
- (C) significant scenic roads, waterways, and views;
- (D) important historic structures, sites, or districts, archaeological sites and archaeologically sensitive areas.

(6) *To maintain and improve the quality of air, water, wildlife, and land resources.*

- (A) Vermont's air, water, wildlife, mineral, and land resources should be planned for use and development according to the principles set forth in 10 V.S.A. Section 6086(a).

(7) *To encourage the efficient use of energy and the development of renewable energy resources.*

(8) *To maintain and enhance recreational opportunities for Vermont residents and visitors.*

- (A) Growth should not significantly diminish the value and availability of outdoor recreational activities.
- (B) Public access to noncommercial outdoor recreational opportunities, such as lakes and hiking trails, should be identified, provided, and protected wherever appropriate.

(9) *To encourage and strengthen agricultural and forest industries.*

- (A) Strategies to protect long-term viability of agricultural and forest lands should be encouraged and should include maintaining low overall density.
- (B) The manufacture and marketing of value-added agricultural and forest products should be encouraged.
- (C) The use of locally grown food products should be encouraged.
- (D) Sound forest and agricultural management practices should be encouraged.
- (E) Public investment should be planned so as to minimize development pressure on agricultural and forest land.

(10) *To provide for the wise and efficient use of Vermont's natural resources and to facilitate the appropriate extraction of earth resources and the proper restoration and preservation of the aesthetic qualities of the area.*

(11) *To ensure the availability of safe and affordable housing for all Vermonters.*

- (A) Housing should be encouraged to meet the needs of a diversity of social and income groups in each Vermont community, particularly for those citizens of low and moderate income.
- (B) New and rehabilitated housing should be safe, sanitary, located conveniently to employment and commercial centers, and coordinated with the provision of necessary public facilities and utilities.
- (C) Sites for multi-family and manufactured housing should be readily available in locations similar to those generally used for single-family conventional dwellings.

(12) *To plan for, finance, and provide an efficient system of public facilities and services to meet future needs.*

- (A) Public facilities and services should include fire and police protection, emergency medical services, schools, water supply and sewage, and solid waste disposal.
- (B) The rate of growth should not exceed the ability of the community and the area to provide facilities and services.

(Source: Agency of Development and Community Affairs)

- citizen participation - by providing nearly any format of map desired for working groups and public meetings
- cooperation among municipalities - by making available comparable data in standard format from adjoining communities
- regional considerations - by allowing comparable data to be aggregated and displayed with a regional perspective.

Planning goals are usually fairly general and long range. Objectives are short range, more specific steps toward meeting the long term goals. They are defined in such a way that success or failure can be determined after a specified interval. For example, a community might set "maintaining a small town atmosphere" as one of its goals. One objective toward meeting that goal might be "discouraging extension of the village areas along the highways."

2 Collect background information needed to meet goals

Once the goals and objectives have been developed, the next step is to collect the background information needed. Vermont law states that ". . . all plans and regulations . . . shall be based upon surveys of existing conditions and probable future trends . . ." and the *Planning Manual for Vermont Municipalities* provides a very comprehensive list of the kinds of resources a community may want to survey (Table 2-2). However, each community will decide for itself what to inventory and map and how to prioritize the work. Inventory and mapping efforts may be phased over a number of years. GIS can play a major role in these efforts in terms of organization, storage, and display of the information collected. For example, Figure 2-1 shows soils information developed by the USDA Soil Conservation Service that has been entered into a GIS as part of a town's inventory.

3 Evaluate and analyze information

As will be explained in the next chapter, the strength of GIS lies in its ability to analyze the information gathered in the inventory and mapping phase. Any combination of data can be requested and displayed in any format. For example, to determine each parcel's physical capability (suitability) for development, information on parcels, soils, slope, and floodplains might be analyzed with the aid of GIS (Fig. 2-2). These different features can be easily combined and "overlaid", thus providing a comprehensive view of the physical constraints to development. In the example shown, the physical constraints to development—slopes greater than 25%, flood plains, farmland soils, wetland soils, shallow soils, and septic limitations—have been entered into a GIS as separate data layers (Fig. 2-2A and Fig. 2-2B). Figure 2-2C

Table 2-2. Background Information for a Municipal Plan

Category	Information

Natural resources	Soils
	  depth to bedrock
	  depth to seasonal high water table
	  suitability for on-site sewage disposal
	  ag potential
	  forestry potential
	Topography - slope
	Surface waters
	  ponds, streams, etc.
	  watersheds
	  water quality
	  flood hazard area, floodway
	  shorelands
	  wetlands - e.g. wetlands map
	Groundwater - aquifer protection areas
	Natural areas
	  geological
	  hydrological
	  biological, e.g. deeryard map

Productive natural resources	Farmland Productive woodland Mines and gravel pits Parcels with potential for the above
Existing land use	
School facilities	Sites Buildings Capacities Bus routes, etc.
Roads	Capacity Traffic volume Accidents Surface condition Maintenance records
Utilities - gas, electricity, cable tv, phone service	Layout and effect on land use patterns Potential hazards

Other infrastructure	Public transportation routes and facilities
	Parking facilities
	Community water systems - public & private
	  facilities
	  service area
	Community sewer systems
	Solid waste disposal
	Emergency services - number and location of
	  personnel
	  vehicles
	  facilities
	Health services - locations and capacities of hospitals, clinics, social service agencies, visiting nurse service, etc.

Recreation facilities	Parks, playgrounds, and areas Programs Organizations responsible School facilities Private facilities (e.g., golf courses, ski areas, etc.)
Special features	Historic sites, building, districts Scenic views & vistas

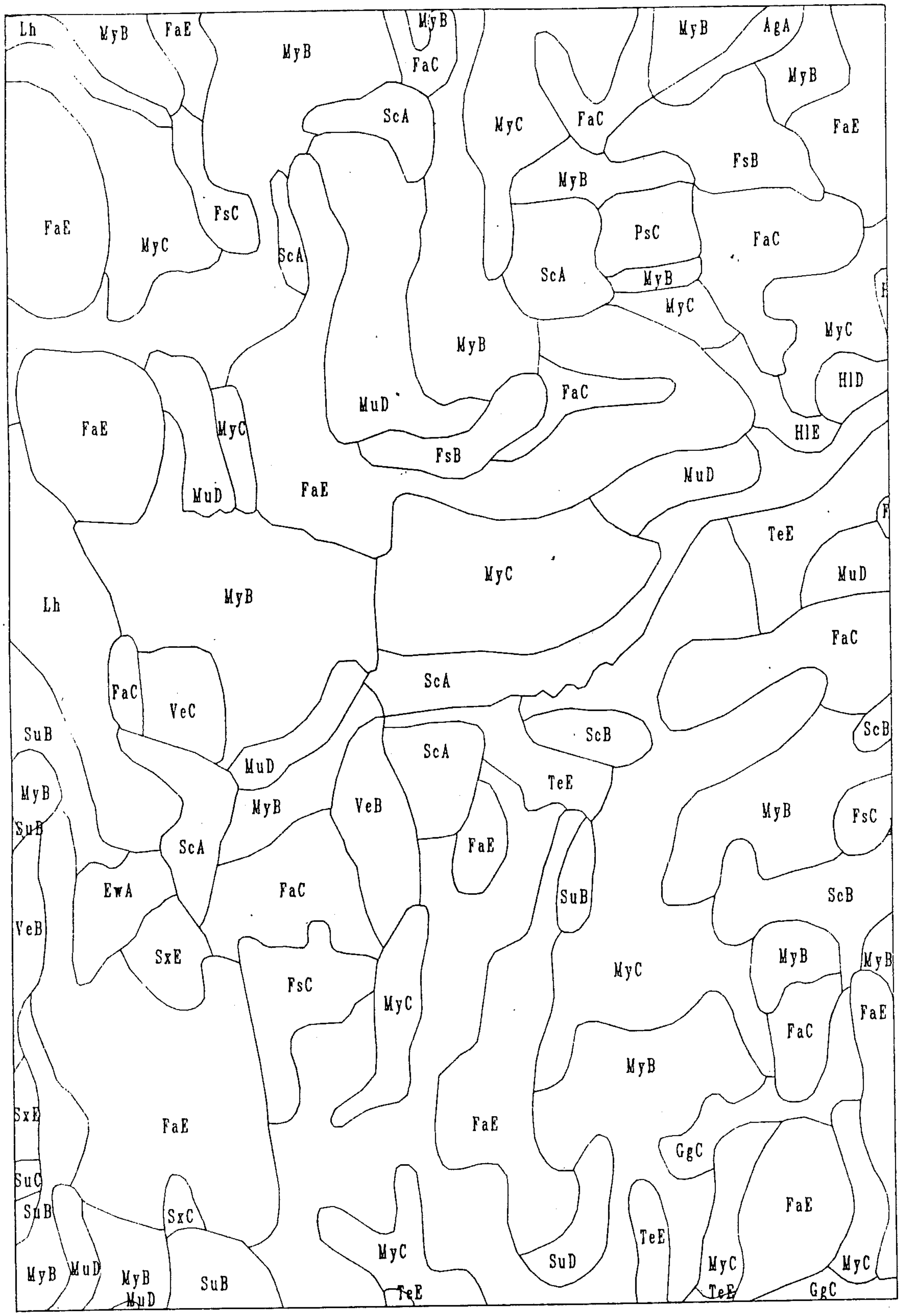


Figure 2-1. Part of a soils layer stored in a community's GIS database.

shows a computer-generated compilation of these constraints. The white portions of the map are the areas that are suitable for development based on the physical criteria used.

Before GIS technology was available, this type of overlay analysis was very difficult to do, relying on the stacking of hand-drawn plastic overlays. The concept, as pioneered by Ian McHarg, was powerful, but the process was inexact and extremely cumbersome when more than two overlays were involved.

Another kind of analysis a planning commission might want to do is a land-use analysis relying on information on parcels, current zoning, and current land use collected during the inventory phase. Figure 2-3 is an example of a current land use map produced for the town of Plainfield, Vermont which illustrates land use categories typical of a Vermont town. Current land use, in combination with existing zoning and parcels may help the planning commission plan for future development and revise zoning by-laws to encourage development patterns that conform to the town's goals.

A community may also want to analyze its "productive natural resources." Two standardized methodologies that can be adapted for this purpose are LESAs and FLESAs. The LESA process (agricultural land evaluation and site assessment) was devised by the USDA Soil Conservation Service (SCS) to provide a uniform methodology for evaluating sites for their physical and economic agricultural viability. Each parcel is rated for such factors as soil chemistry and physical properties, and such non-soil properties as site size, agricultural infrastructure, and land use regulations. Using GIS technology, these ratings are easily tallied and the results displayed for visual and numerical comparisons. Similarly, FLESAs (forest land evaluation and site assessments) were devised by the Vermont Department of Forests, Parks, and Recreation to assess the productive potential of forested sites. Again, using locally determined criteria and weighting factors, each site is rated. When the results are tallied, the sites can be objectively compared. FLESA is still relatively new but already the town of Granby, Vermont, concerned about the future of its forests, has decided to utilize GIS in the FLESA process.

Other community resources that should be evaluated for adequacy both in terms of the present and population projections for the future include

- housing,
- school facilities,
- roads,
- public transportation,

- parking,
- health services,
- water supply,
- sewer system,
- solid waste disposal, and
- emergency services.

4 Identify community needs and options for the future

By developing goals, inventorying resources, and analyzing them, Vermont communities will be in a position to identify needs and options for the future pertaining to natural resources, land use, community facilities and services, and community development. For example, if maintaining productive forest land is a community goal, a FLESA inventory and analysis (or a similar process) will yield information on the relative merits of forested sites. Various avenues for keeping these sites productive can then be explored—zoning, tax incentives, purchase of development rights, etc. Maps can help a community visualize the impact of the various possible actions. GIS is particularly helpful because maps representing several alternative scenarios (with parcel acreages automatically computed) are quickly made for easy comparison.

Similarly, a land use analysis may identify current commercial centers and potential sites for commercial expansion. By mapping several "alternative futures" using GIS, a community can visualize choices and make informed decisions. Alternative sites for community facilities such as public parking, and community development projects such as affordable housing can be analyzed and presented for public discussion in the same way.

5 Develop municipal plan

Development of the municipal plan will rely on the results of the previous four steps. It will be necessary to project future land use based on housing and population projections, economic conditions, zoning, community facilities and services needs, and to consider compatibility of proposed land uses and their consistency with overall community goals. Location of potential sites for each use should be based on the land requirements for each and on the map of physical constraints for development (such as that developed for Woodstock in Figure 2-2). For example, a community recreation area might have requirements of a minimum acreage, relatively flat land, lake frontage with beach potential, and a certain distance from an existing public road; a condominium development would have slope and septic disposal requirements.

When developing a municipal plan, it is very useful to know what the effects of the proposed zoning would be on the future size, and settlement patterns of the town, as well as the total increase in housing sites that might result. GIS can be used to help a town visualize and quantify this. "Build-outs" using GIS have been done by the Town of Weston and the City of Burlington.

6 Develop implementation program

If the municipal plan is to have any impact on a community, it must be implemented. At a minimum, the plan should be reflected by the capital budget. For example, if a new firehouse or school is called for in the plan it will need to be included in the budget. In most communities, the plan will also be implemented through zoning by-laws (including a zoning map), subdivision regulations, and shoreland and flood hazard by-laws (and maps).

Maps are critical to the development of zoning by-laws. Figure 2-4 is an example of a zoning map for the Town of Charlotte, Vermont based on current land use, wetlands, shorelands, and other information. One of the advantages of using GIS to develop such a zoning map is the ease of making subsequent modifications, which, in fact, the Town of Charlotte has done. GIS-generated zoning maps can be modified when necessary at a lower cost to the town than conventional hand drawn maps.

In larger communities specific programs for community development, farmland protection, and community housing may be instituted in order to carry out the municipal plan. Again, these programs will reflect the results of the inventory and analysis stages.

7 Implement plan

GIS can also be very beneficial in several aspects of plan implementation such as

- infrastructure management;
- zoning enforcement and permit tracking;
- variance application review; and
- grand list maintenance.

However, using GIS in these capacities will almost always require that the community have ready access to computer hardware and to at

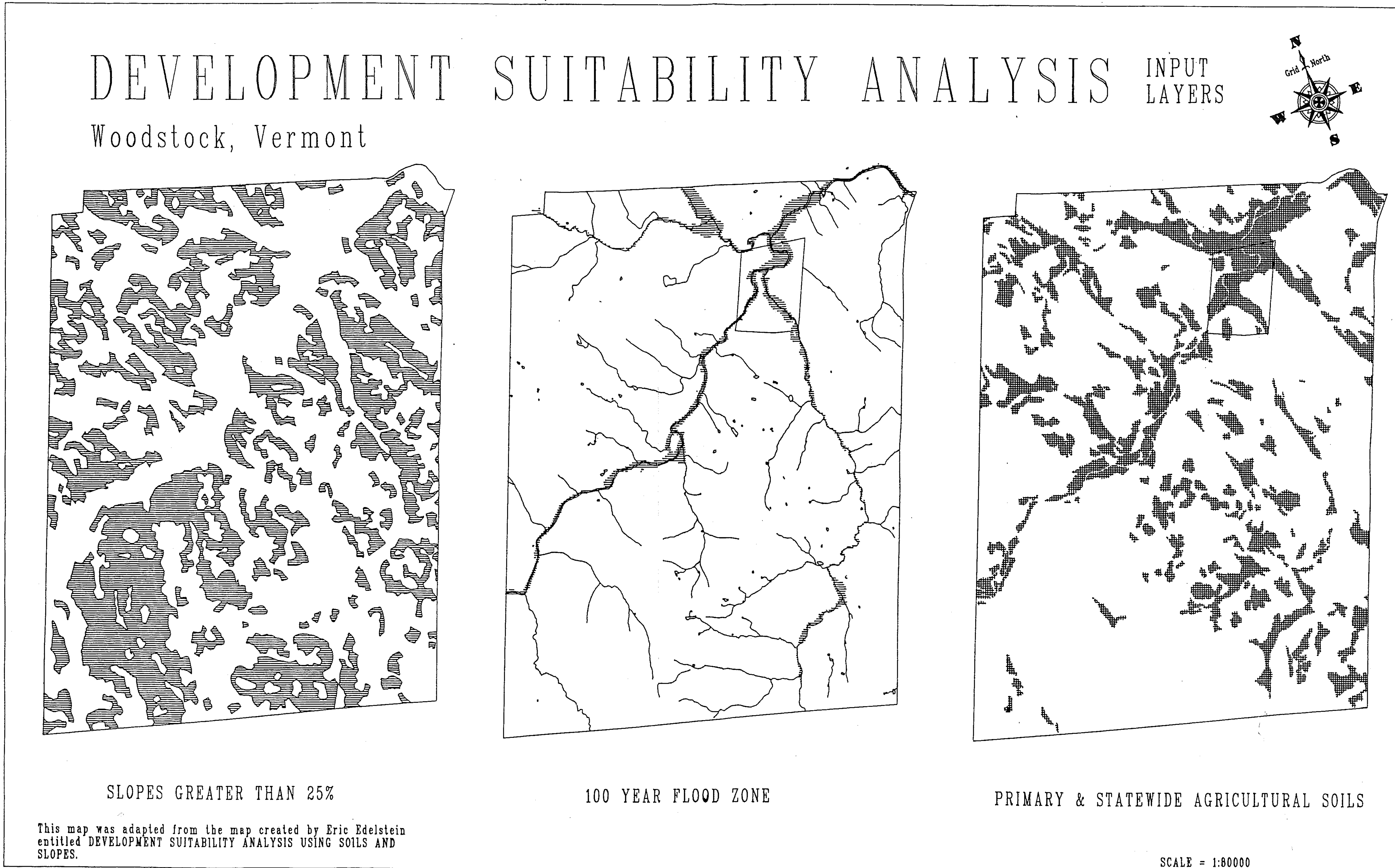


Figure 2-2A. Three of the layers overlaid in a GIS development suitability analysis.

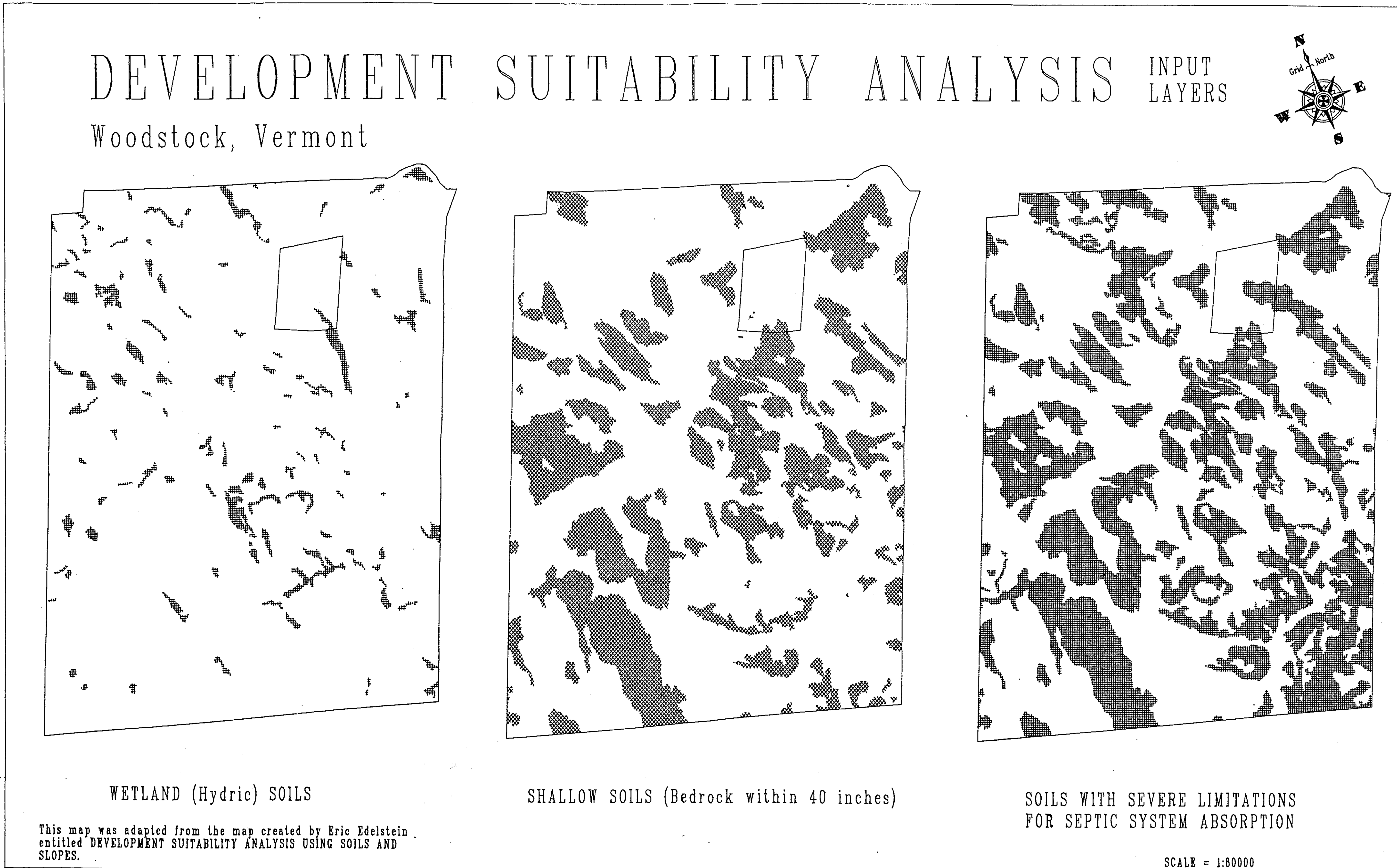


Figure 2-2B. Three of the layers overlaid in a GIS development suitability analysis.

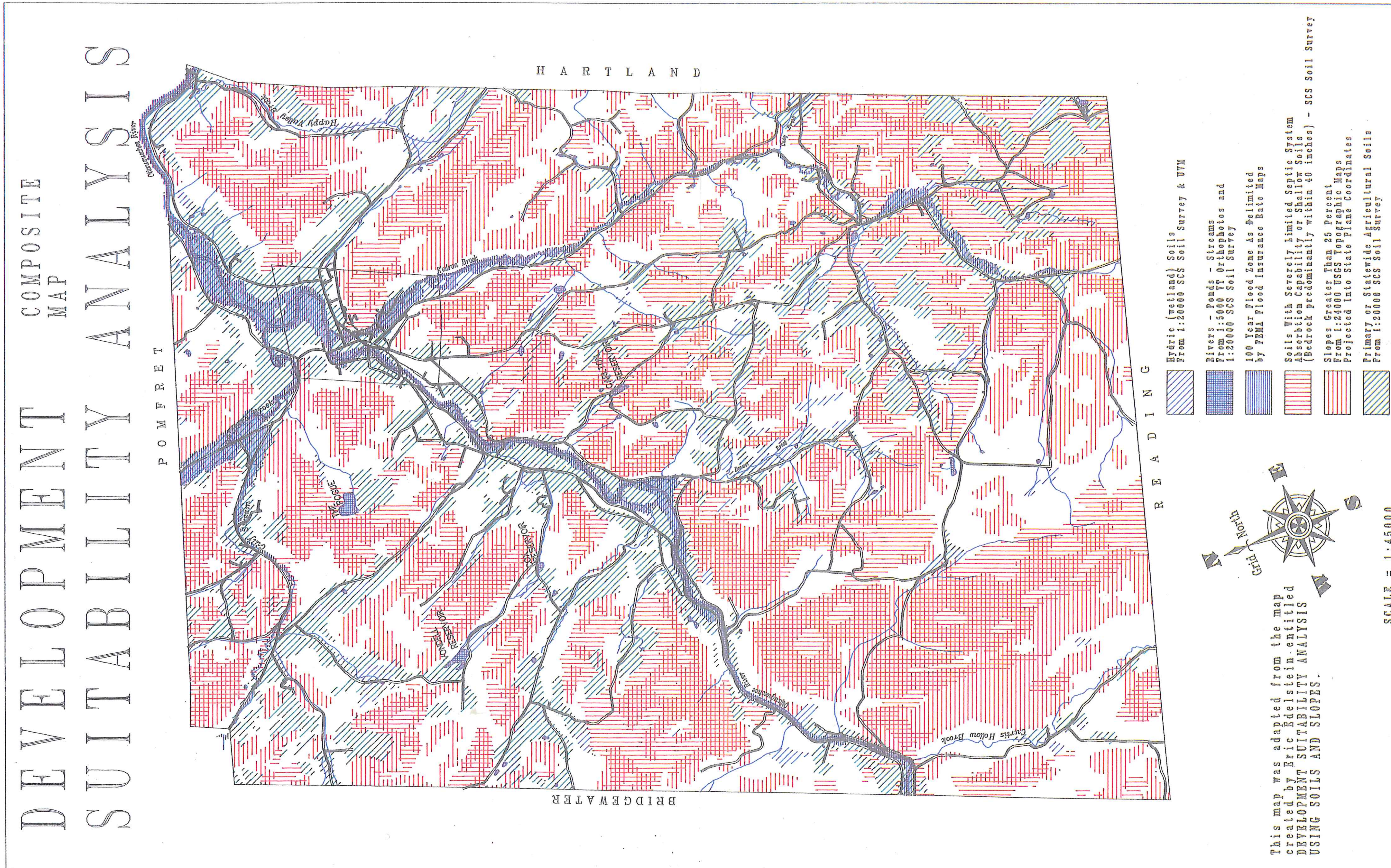


Figure 2-2C. The white areas on the map are the most suitable for development based on the criteria used in the development suitibility analysis.

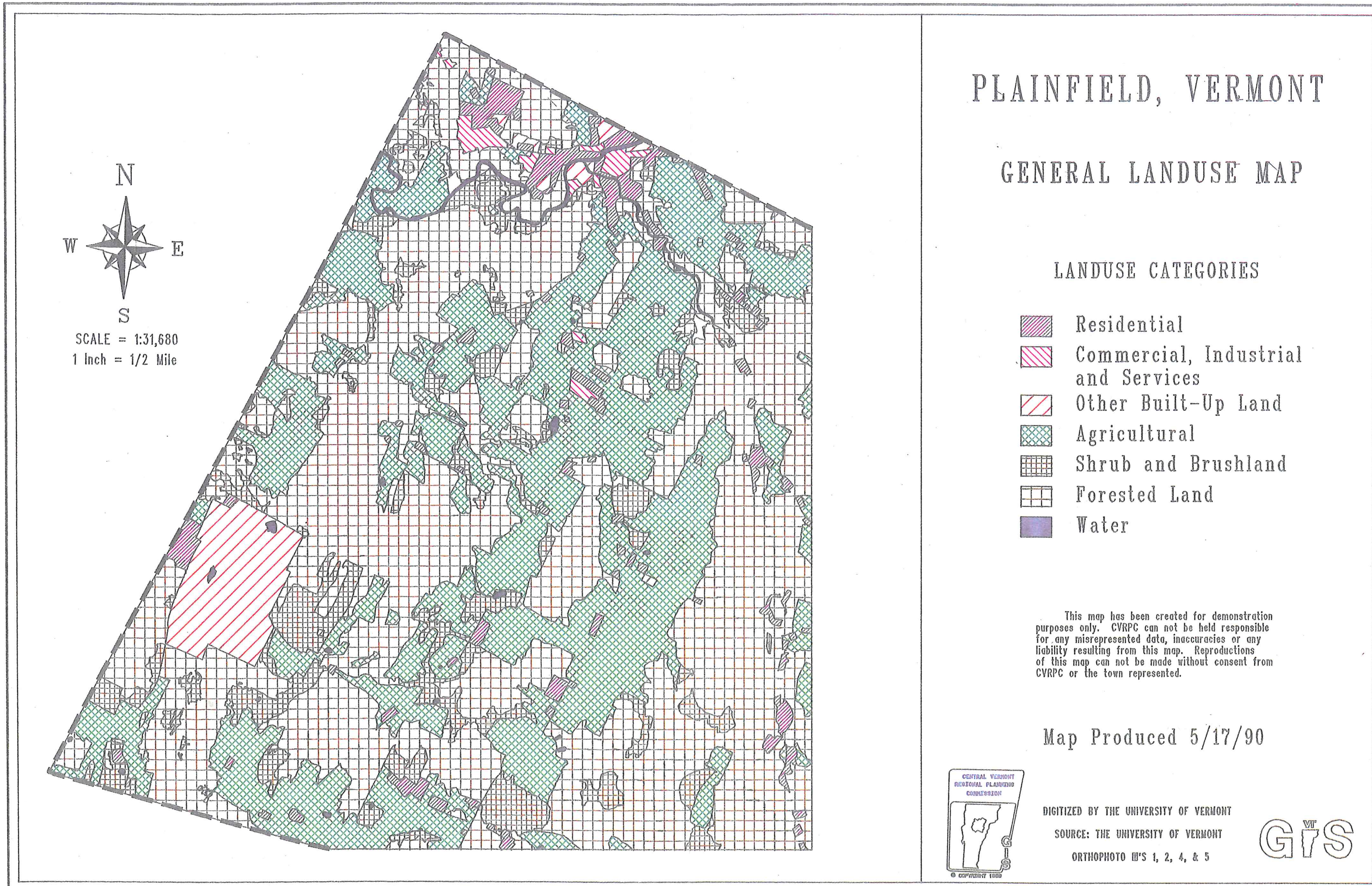


Figure 2-3. Current land use for the Town of Plainfield. Such a map is helpful when developing or revising zoning by-laws.

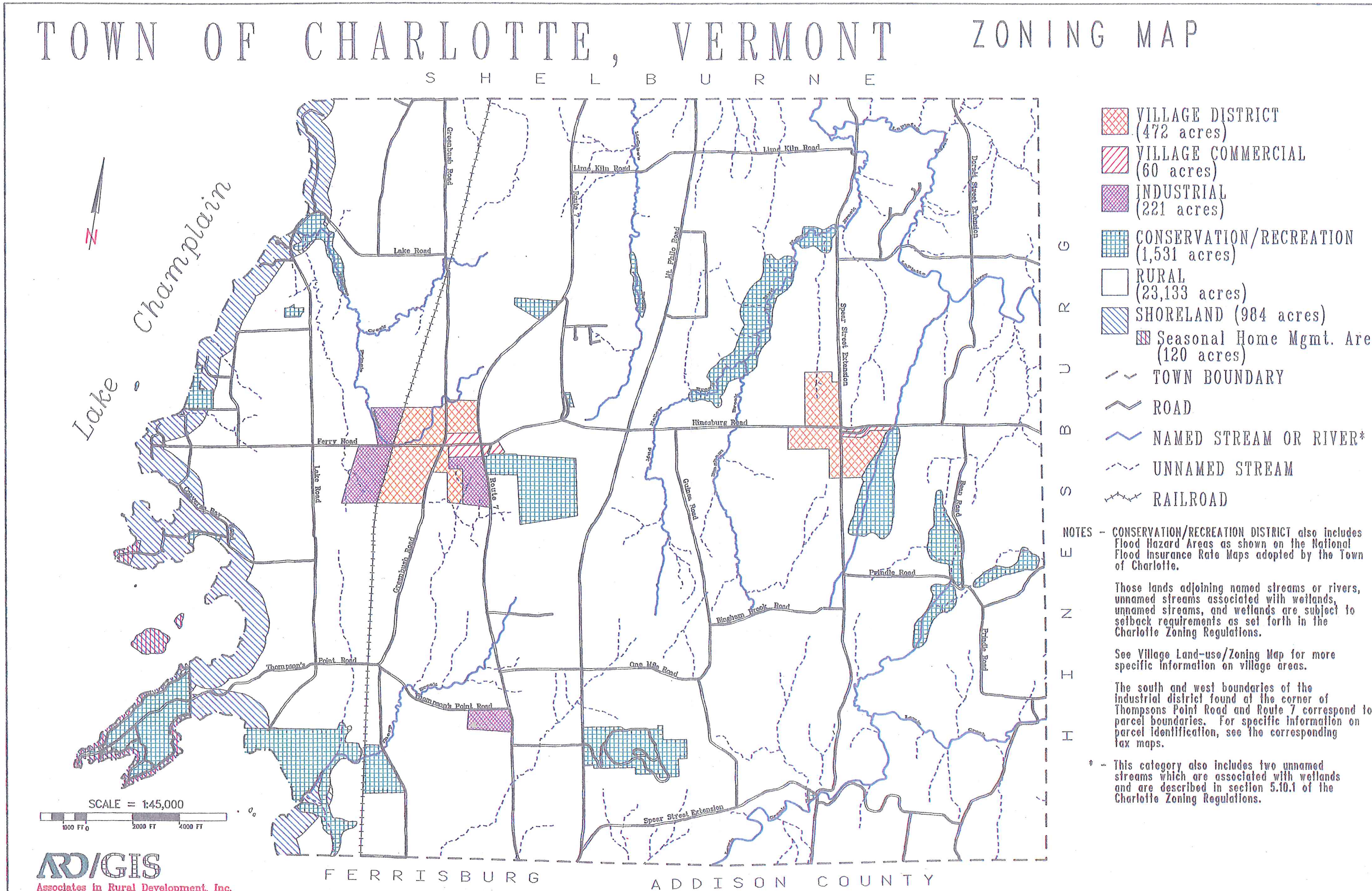


Figure 2-4. The Charlotte zoning map has been updated several times using GIS to reflect changes in zoning district boundaries.

least some GIS software in their own municipal offices or through a contractor or regional planning commission (see Chapter 5).

8 Update plan

To be valid, a municipal plan must be updated and adopted every five years. The revised plan should be based on land use changes, road conditions, planned improvements, zoning changes, and statistical data on population, housing, and development. If the maps and inventories for the original plan were developed using GIS, it will be a relatively simple matter to update the database and create new maps and reports. If a manual effort has to be repeated, the plan revision will be slow and difficult, making it likely that the revised plan will be based on outdated information.

Summary

Maps and GIS can make a great contribution to the municipal planning process particularly in

- resource inventory,
- resource analysis and modeling,
- preparation of graphics for public display, and
- updating inventories, plans, and zoning district boundaries.

References

McHarg, I. L. 1971. *Design With Nature.* Doubleday/Natural History Press. Garden City, New York. 197 pages.

Vermont Department of Housing and Community Affairs, 1987. *Planning Manual for Vermont Municipalities.*

State of Vermont Department of Housing and Community Affairs, July 1988. Title 24 *Vermont Statutes Annotated,* Chapter 117, Section 4302. Vermont Municipal and Regional Planning and Development Act as amended by the 1988 Growth Management Act (Act 200).

Chapter 3 What is a GIS?

In Chapter 1 we reviewed the many uses communities have for geographic information. In Chapter 2 we focused on the role of maps in the planning process. Now we turn our attention to the geographic information system (GIS) technology which promises to answer many of the information management and analysis needs of communities large and small. Substantial improvement in computer systems in recent years has made it much easier to apply this technology to the problem of storing, manipulating, and analyzing large volumes of spatial data. These improvements have resulted in, among other things, computers that are smaller and more powerful than their counterparts of previous decades, and thus more affordable and readily accessible to local and government and regional planning commissions.

GIS Definition

A *geographic information system (GIS)* is a system of computer hardware and software designed to allow users to collect, manage, and analyze large volumes of geographical data and the associated attributes (tabular or descriptive information).

What distinguishes a GIS from standard database management programs such as those that a bank, library, or town lister might use, is this ability to store and analyze (*spatial information*) and display it in map form. Other names for geographic information systems include land information systems, natural resource information systems, and spatial information systems.

Map Layers

In order to process spatial information, a GIS stores the information in a series of layers, each geographically tied to known earth coordinates (i.e., registered to a controlled base so that each layer correctly lines up with the others). Each data layer consists of a related set of *map features,* such as ponds and streams, and their associated nongraphic information or "attributes," such as the name of the waterbody and information on its water quality. This concept is illustrated in Figure 3-1 where we see eight themes of map information, each assigned to its own data layer. The first layer contains political and other administrative boundaries. The second layer represents zoning districts. The third shows utilities. In layer four we have parcel information including boundaries and parcel identification numbers (IDs). Planimetric features—the locations of buildings, roads and streams—

are included in layer five. Layer six contains a grid representing the State Plane Coordinate System. Topographic *contours* (lines of equal elevation) are stored in layer seven. And, finally, layer eight shows the locations of geodetic and survey control. Because each layer is carefully registered to earth coordinates (such as the Vermont State Plane Coordinate System), the features in the various map layers can be precisely superimposed or stacked as indicated by the vertical lines linking the layers in Figure 3-1.

In general, each map layer consists of only one type of map feature. That is to say that *point features* are stored on one layer, *line features* on another, and *polygon features* on another. This facilitates the storage and subsequent analysis of the information by the computer. So, for example, the planimetric features illustrated in layer five of Figure 3-1 would, in reality, be separated into individual layers. Depending on the scale of the database being developed, houses would be assigned to a point layer, roads to a line layer, and large water bodies (e.g., rivers) to a polygon layer. Separating the data into layers provides great flexibility in terms of analysis and display. We can select only the layers needed for a given application, analyze them efficiently, and present them in an informative and attractive format.

Paper maps (and digitized data) exist in many different map projections (see Chapter 9). While this causes alignment problems when manually overlaying map layers, a GIS has the capability to mathematically transform map features from one projection to another, thereby allowing map layers derived from different sources to be successfully used together. For a GIS to be able to accomplish this, each source map must have at least four points with known coordinates and its map projection must be known.

Attribute Information

In addition to the spatial information stored for each feature, there is associated *attribute* or *tabular information.* For example, for each parcel stored in layer four of Figure 3-1, we could store parcel owner, owner's address, and the valuation. Each mapped feature is linked to its accompanying attribute data by means of a unique code or ID. In the case of the parcel layer the unique code is the parcel ID. The attribute file associated with layer four might look something like the following example:

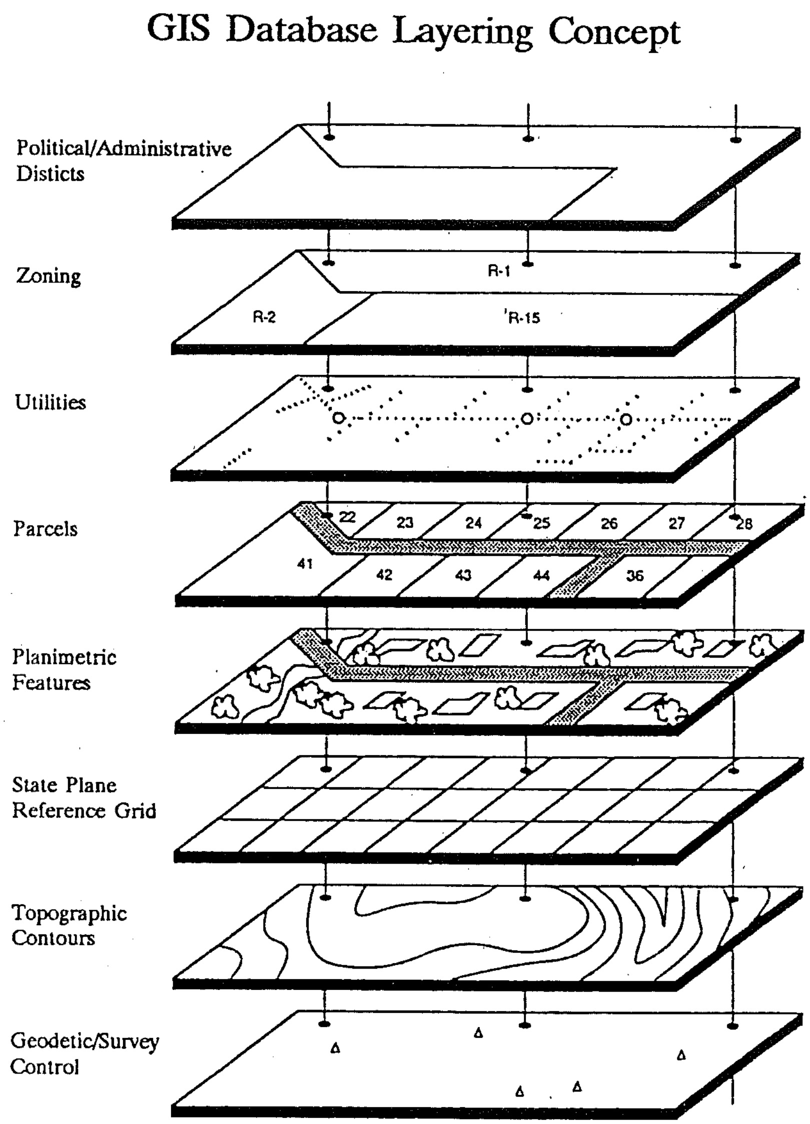


Figure 3-1. Each category of map information is assigned to its own data layer in a GIS (courtesy OGIS).

PARCEL ID	PARCEL OWNER	PARCEL ADDRESS	PARCEL VALUATION
41	Marshall, Raymond	11 Pine Street	$120,000
42	Doe, Joan	13 Pine Street	$125,000
43	Bartlett, John	15 Pine Street	$115,000
44	Bartlett, John	3 Cedar Street	$150,000

The information associated with each map feature can be selectively retrieved and displayed. For example, the assessor might want to see the locations of properties valued at more than $125,000. The appropriate parcels can be easily displayed with an accompanying list. If the public works department wanted to contact the property owners along Pine Street about upcoming water main repairs, a mailing list could be easily prepared from a simple query of the information in the GIS database.

Relational Databases

If the database has been well designed, we should be able to relate a mapped feature to a wealth of other associated information. For example if the parcel number is recorded when building permits are issued, a community has a means of tracking and mapping permits by parcel number thus allowing the assessor and planning commission to visualize where growth is taking place within the town (Figure 3-2). The permit file and the parcel file must have a common item, or *relational item,* that allows us to link the information from the two files. This is what is meant by a *relational database.* In our parcel example, the parcel ID is the relational item. There are many relational database software products on the market today. However, the strength of GIS software is its ability to link the graphic (map) and non-graphic (tabular) information.

Topological Databases

For many of the geographic analyses we may want to carry out, we'll need to know what is connected to what, what's next to what, etc. In order to provide these analytic capabilities, the GIS database is structured so that each feature has information stored about its own position and about the position of surrounding lines and features. This is information that ordinary relational databases (and computerized drafting packages) do not include. These spatial relationships of map features are referred to as *topology.* In order to qualify as a true GIS, a database must be topological.

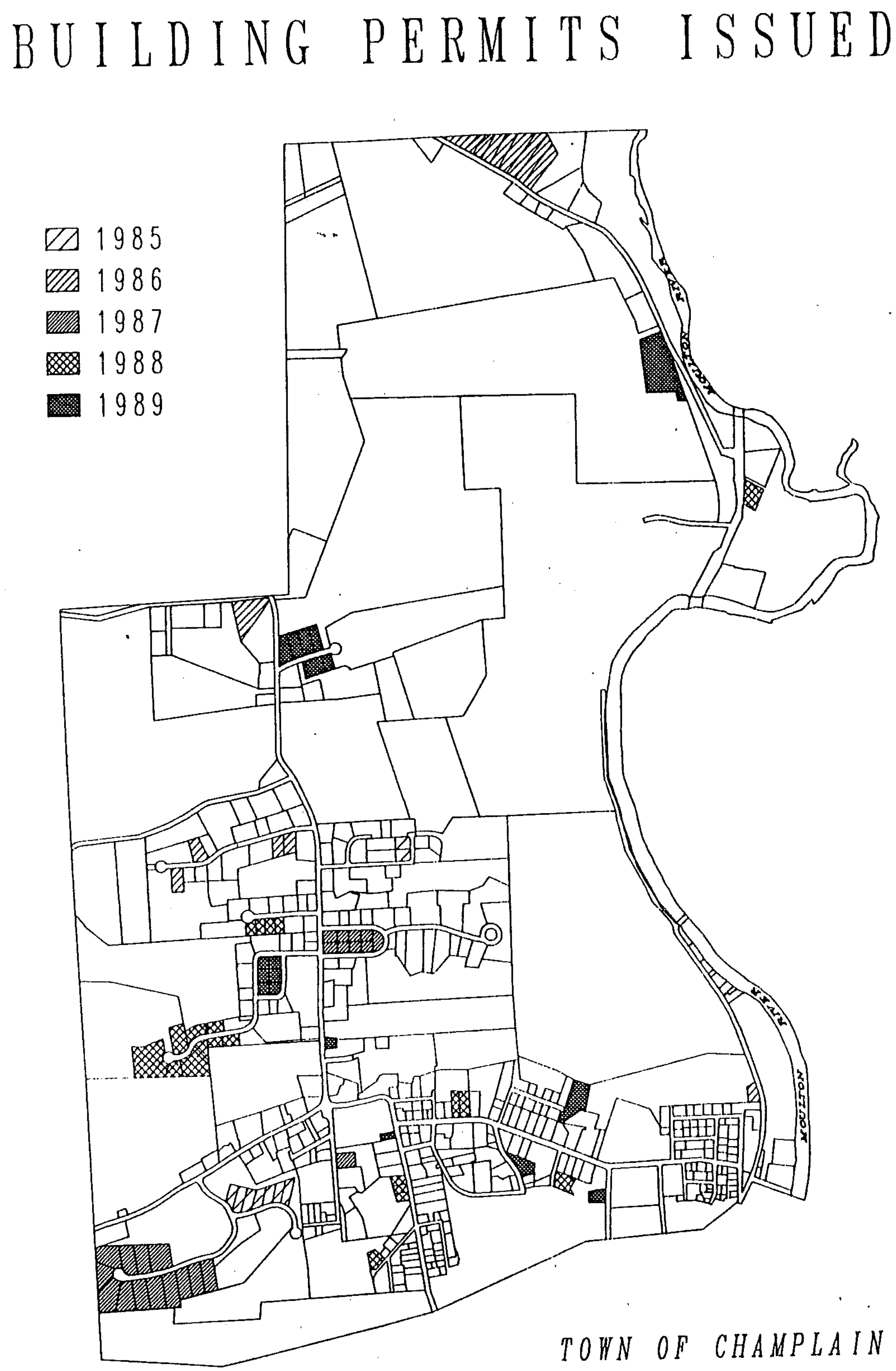


Figure 3-2. By mapping parcels where building permits have been issued, a community can visualize where growth is occurring.

In a topological structure, map features are represented by arcs, nodes, and polygons. A line (e.g., a stream)is comprised of one or more *arcs.* Each arc has a starting and ending *node.* A point feature (e.g., a utility pole) is simply represented as a node. A *polygon* consists of a series of arcs that closes on itself. A polygon defines the boundaries of a discrete area (e.g., a parcel). Figure 3-3 shows how a topologically structured database can store information about the spatial connectivity and adjacency relationships of map features in addition to their absolute positions on the face of the earth.

The combination of a topological and a relational database is what makes a GIS so powerful. We can ask what, where, and how far questions, not only within one map layer, but also between layers. For example, referring to the parcel data again, if Joan Doe of 13 Pine Street applies for a zoning variance in order to operate a home day care facility, we can quickly determine the zoning class for her parcel (because the zoning layer and parcel layer are co-registered in our database). What's more, by submitting a spatial query to the computer, a list of the property owners within 500 feet of her property—all of whom must be notified for a zoning hearing—will be generated.

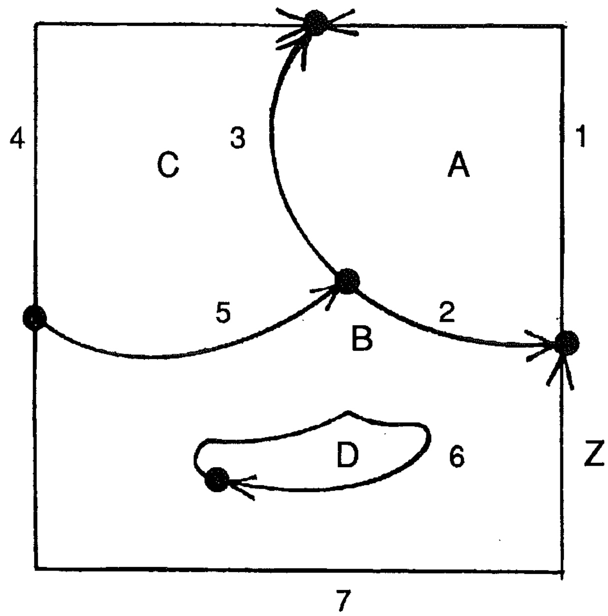
Let's look in more detail at the kinds of things we can do with this topological, relational database. GIS analyses can be broken into two basic categories: surface analysis and overlay analysis. A surface analysis applies to relationships within one data layer and often results in the creation of a new data layer. Examples of this type of analysis include reclassification, merging, surface generation, and distance, area, and perimeter measurements.

Reclassification is simply done by specifying a reclassification rule for attribute data. For example, we could convert detailed soil classes that include a slope designation (e.g., MeA, MeB, MeC) to a less detailed scheme simply by providing a rule such as

all Melville soils	*= Me*
all Barton soils	*= Ba*
all Carltons soils	*= Ca.*

One more command to the GIS will instruct it to merge the new polygons as appropriate, by dissolving internal boundaries (Figure 3-4).

An example of surface generation is the creation of a slope map from elevation point data. The elevation data could be entered as contour lines (Figure 3-5A) or as digital elevation data, which is becoming increasingly available from USGS and as a by-product of Vermont's orthophoto production (see Chapter 7). Once elevation is entered into the computer, a specialized routine is called upon to calculate slopes into specified classes. The resulting slope map is a new data layer that can be retrieved and displayed on its own (Figure 3-5B) or used in further analyses such as creating a map of aspect or a 3-D map. The slope information thus generated is useful in such processes as defining zoning districts or developing timber harvest plans.



POLYGON	NUMBER of ARCS	LIST of ARCS
A	3	-1,-2,3
B	4	2,5,-6,-7
C	3	-3,4,-5
D	1	6

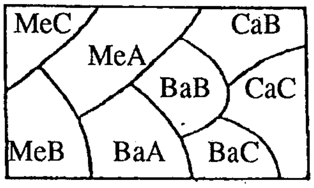
ARC NO.	LEFT POLYGON	RIGHT POLYGON
1	A	Z*
2	A	B
3	C	A
4	Z	C
5	C	B
6	B	D
7	B	Z

Z* the "universal polygon," or area beyond the mapped area

Figure 3-3.
In a topological database each polygon consists of a series of arcs. Arcs have a + or - sign associated with them which is determined by the direction of digitizing with respect to the center of a given polygon. Since each arc also has a left and right polygon value, it is easy to know which polygons are contiguous. *(Adapted from ESRI's* PC-ARC/INFO Starter Kit, *1989.)*

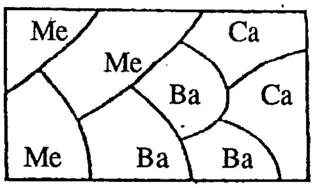
Figure 3-4. Reclassification of Attributes

Original Attributes



Reclassification Rules
All Mes = Me
All Bas = Ba
All Cas = Ca

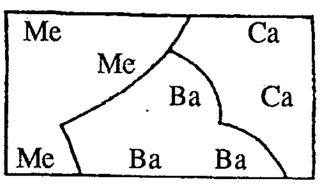
Results of Reclassification



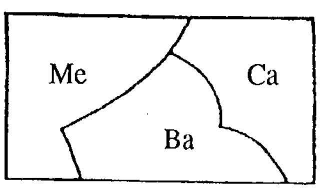
3-4A.

In this example a generalized soils map is created from a detailed soils map by eliminating distinctions based on slope (e.g., slope A, slope B, slope C).

Results of Dissolve



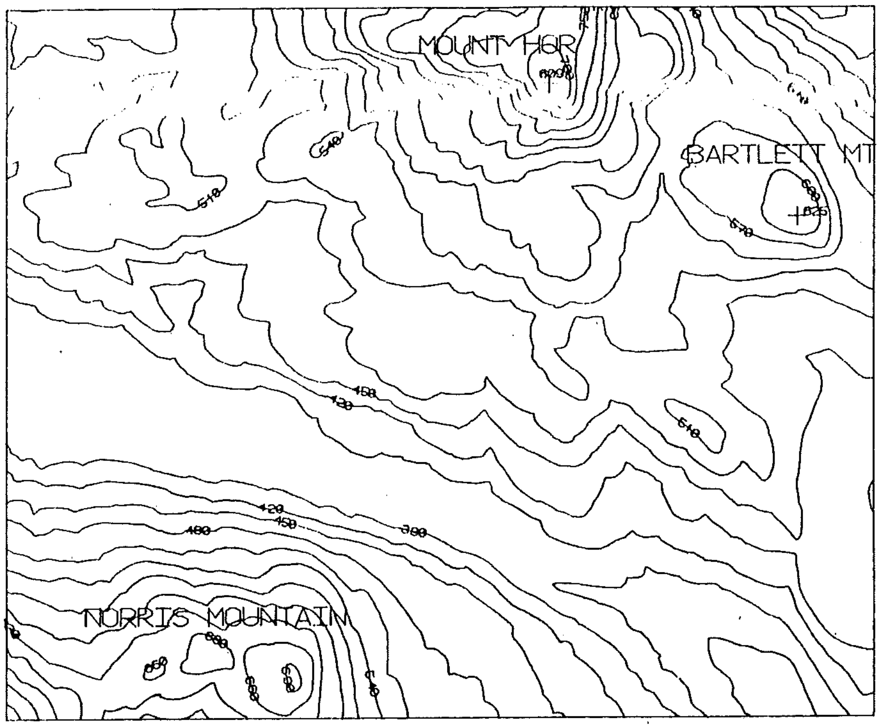
Result of Merge



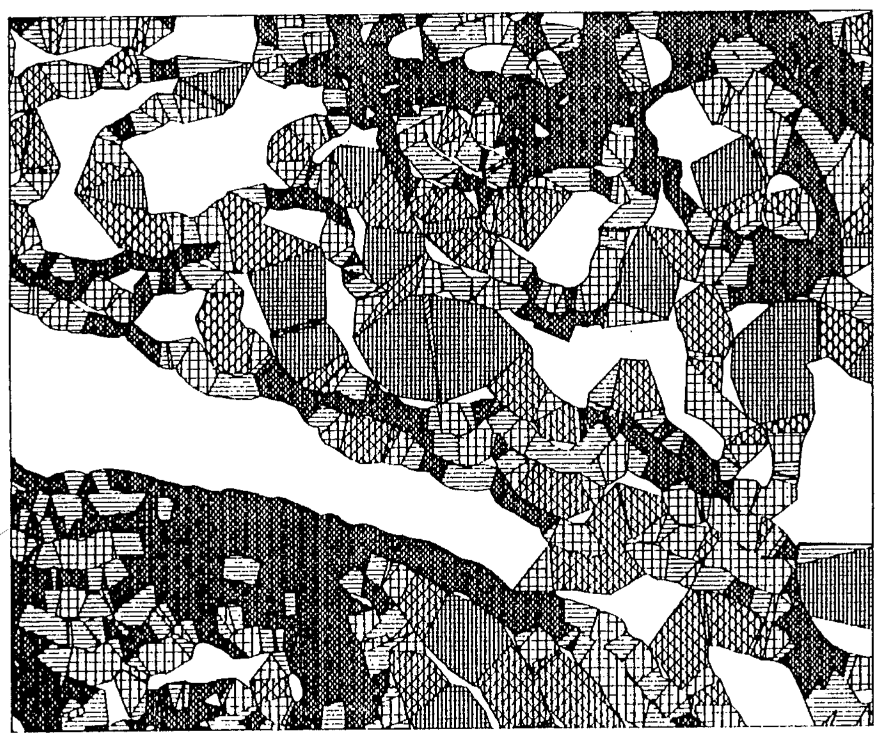
3-4B.

The process of dissolving internal boundaries and merging polygons with identical attributes (i.e., soil classes) completes the generalization process. *(Adapted from Tomlinson & Boyle, 1987)*

3-5A



3-5B



Figures 3-5A and 3-5B. In A, elevation information in the form of contour lines has been entered into the GIS. In B, seven slope classes have been created from the contour data by a GIS program known as"TIN" (triangulated irregular network).

Distance, area, and perimeter measurements are automatically performed by a GIS. For example, once parcel boundaries are entered into the computer, the computer automatically figures the acreage of each parcel and its area as a percentage of the total area of the community. This can be printed out as a tabular report and compared to existing acreage estimates to aid in updating parcel information. If an accurate town road network has been entered into the database, we can ask the computer to sum the road lengths within a given subdivision. The public works or highway department could then use this information to estimate the costs of maintaining these streets (paving, plowing, etc.) should they become the responsibility of the town or city.

Overlay analysis involves examining two or more of the data layers simultaneously. For example, as Figure 3-6 illustrates, a community might want to consider slope and present land use in developing zoning regulations. After present land use and slope classes are entered into the computer, they are combined, using the computers overlay functions, to create a new map layer, and a paper or mylar map is then plotted indicating areas where present land use and slope conditions should limit further development. The zoning regulations can then be written or modified to reflect these limitations.

A corridor analysis is a special kind of overlay analysis. An example would be comparing proposed routes for a pipeline through an agricultural region. The center lines for several proposed routes could be entered into the computer. Next, the width of the right-of-way is simply typed in. The computer generates a map of each proposed corridor which then can be overlaid on other relevant data layers—soils, buildings, transportation (Figure 3-7). For each proposed route, the computer can calculate the amount of prime agricultural soil that would be lost, the numbers and kinds of structures within the right-of-way, the number of roads and railroads to be crossed. In this way, objective, quantitative information can be provided for the decision-making process.

Figure 3-8 shows a typical PC-based GIS installation consisting of a digitizing table for data entry, a personal computer (keyboard, monitor, and processing unit) for data storage and analysis, and a pen plotter for the production of hardcopy maps. Not shown in the photograph is the printer, used for text and tabular output. For a discussion of GIS software, hardware, and computer communications, please refer to Appendix 3.

Output Scale

A GIS can produce maps at any size up to 36 by 48 inches to fit a user's needs. These maps can depict an entire community or a portion, such as a village or a historic district. Also, because all layer information is stored by coordinate location, it is easy to combine layers even if their sources are at different scales. However, the user must be careful about mixing together inappropriately scaled information. When combining layers of different source scale it is important to list all disclaimers related to accuracy.

Figure 3-6A.

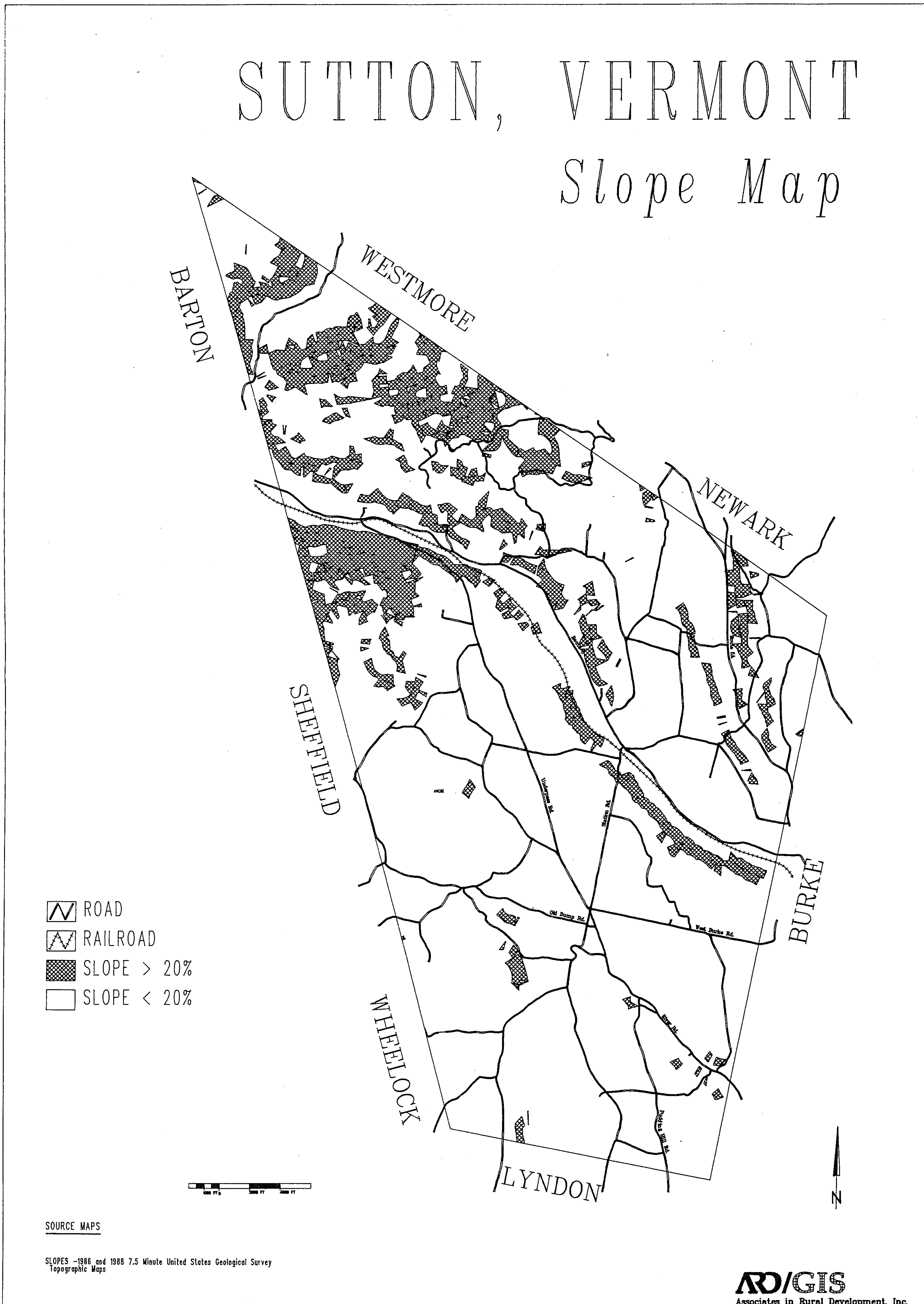


Figure 3-6A. Slope information used in a GIS overlay.

Figure 3-6B.

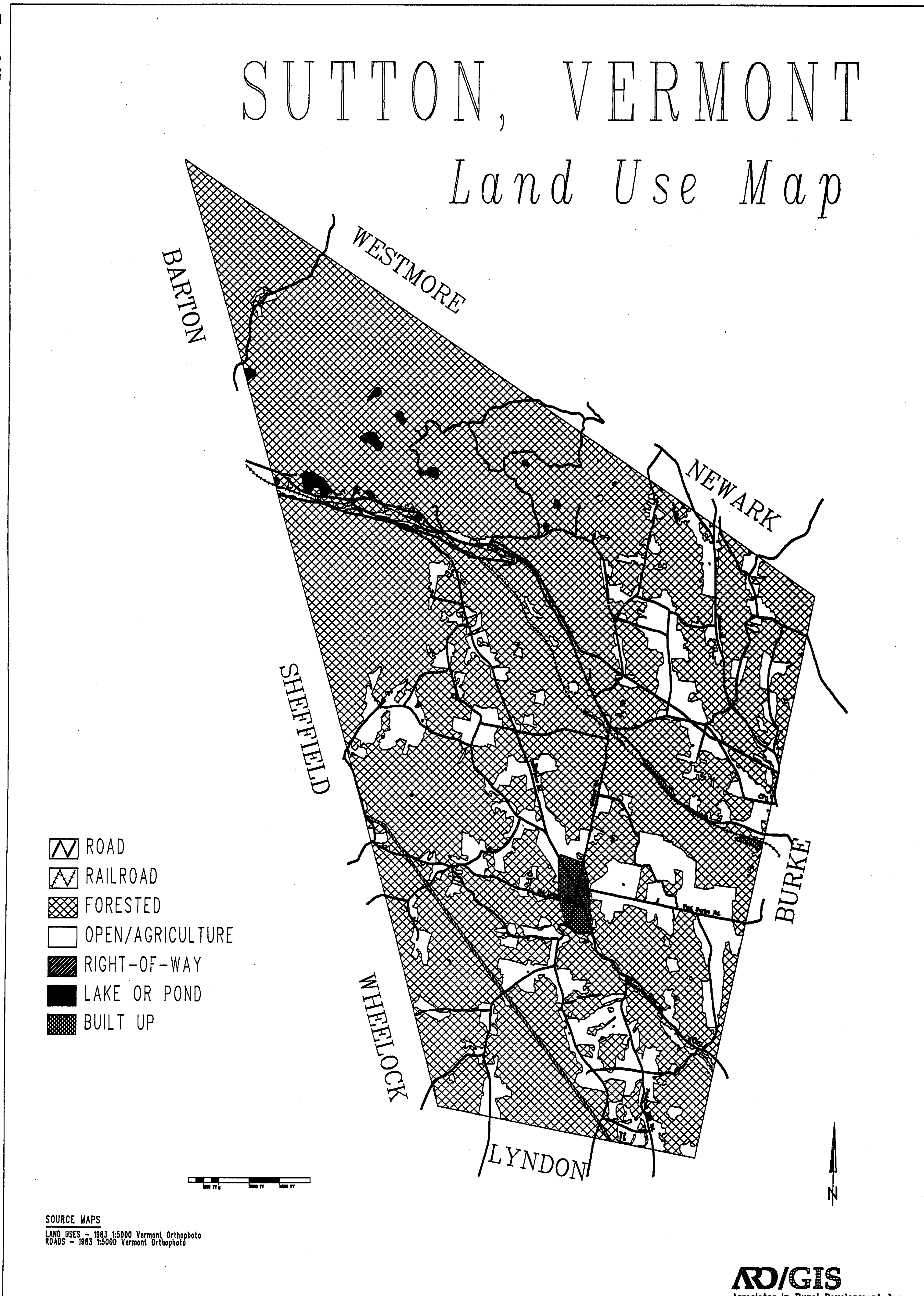


Figure 3-6B. Current land-use information used in a GIS overlay analysis.

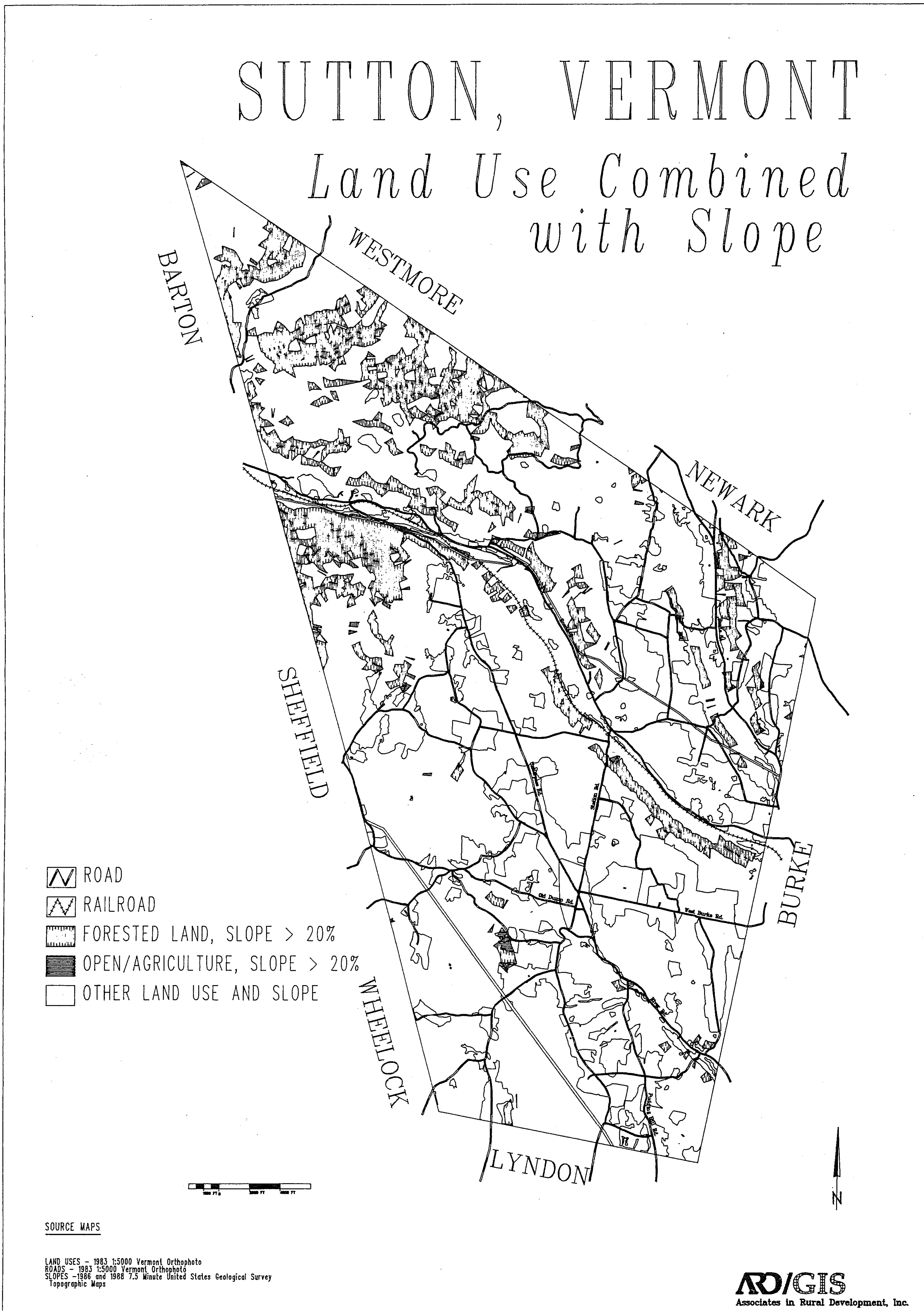
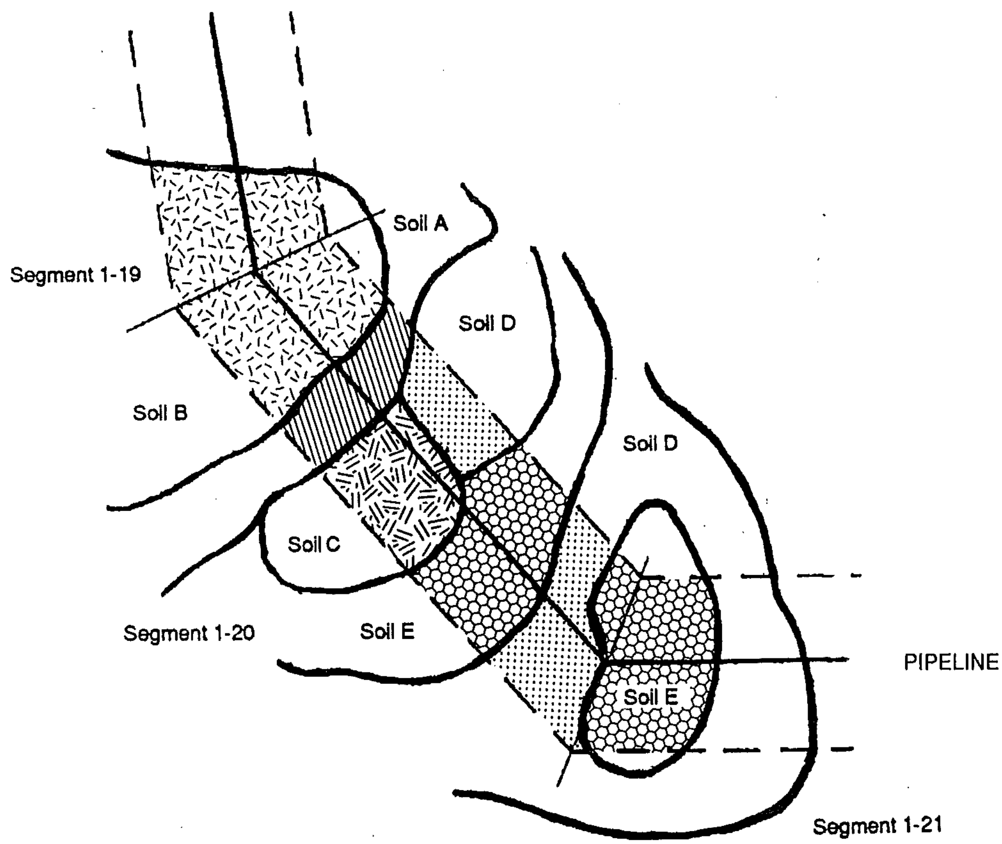


Figure 3-6C. The result of the overlay process highlights forested and agricultural land with a slope of over 20% that could be considered for zoning as a conservation/recreation district.

Figure 3-6C.

PIPELINE CORRIDOR ANALYSIS



Soils in Pipeline segment 1-20	
	acres
Soil A	50
Soil B	130
Soil C	80
Soil D	80
Soil E	110

Figure 3-7. As part of a corridor analysis, a proposed pipeline right-of-way is overlaid over soils information. The number of acres of each soil type within each segment of the pipeline corridor is automatically calculated by the GIS. By referencing the SCS agricultural potential of the soils and the current land-use layer in the GIS database, the amount of prime agricultural land that would be taken out of production can be calculated.

Distance, area, and perimeter measurements are automatically performed by a GIS. For example, once parcel boundaries are entered into the computer, the computer automatically figures the acreage of each parcel and its area as a percentage of the total area of the community. This can be printed out as a tabular report and compared to existing acreage estimates to aid in updating parcel information. If an accurate town road network has been entered into the database, we can ask the computer to sum the road lengths within a given subdivision. The public works or highway department could then use this information to estimate the costs of maintaining these streets (paving, plowing, etc.) should they become the responsibility of the town or city.

Overlay analysis involves examining two or more of the data layers simultaneously. For example, as Figure 3-6 illustrates, a community might want to consider slope and present land use in developing zoning regulations. After present land use and slope classes are entered into the computer, they are combined, using the computers overlay functions, to create a new map layer, and a paper or mylar map is then plotted indicating areas where present land use and slope conditions should limit further development. The zoning regulations can then be written or modified to reflect these limitations.

A corridor analysis is a special kind of overlay analysis. An example would be comparing proposed routes for a pipeline through an agricultural region. The center lines for several proposed routes could be entered into the computer. Next, the width of the right-of-way is simply typed in. The computer generates a map of each proposed corridor which then can be overlaid on other relevant data layers—soils, buildings, transportation (Figure 3-7). For each proposed route, the computer can calculate the amount of prime agricultural soil that would be lost, the numbers and kinds of structures within the right-of-way,

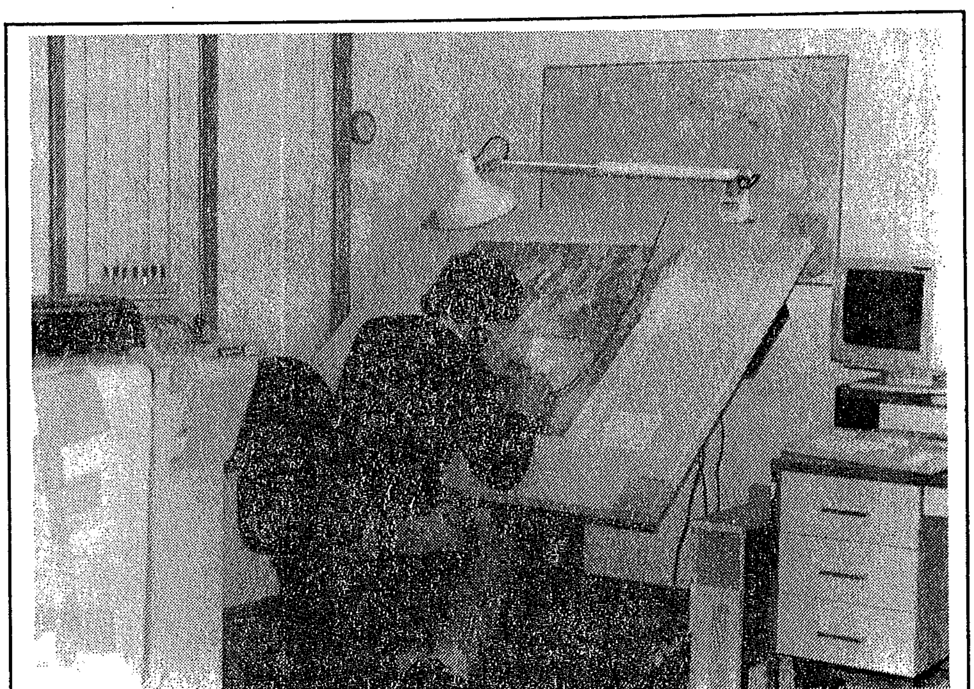


Figure 3-8.
A typical PC-based GIS setup, showing—from left to right—a pen plotter, a digitizing table, the computer resting in a floor stand, and the monitor and keyboard on the desk. Also connected to the computer is a printer to create text and tabular output.

the number of roads and railroads to be crossed. In this way, objective, quantitative information can be provided for the decision-making process.

Figure 3-8 shows a typical PC-based GIS installation consisting of a digitizing table for data entry, a personal computer (keyboard, monitor, and processing unit) for data storage and analysis, and a pen plotter for the production of hardcopy maps. Not shown in the photograph is the printer, used for text and tabular output. For a discussion of GIS software, hardware, and computer communications, please refer to Appendix 3.

Output Scale

A GIS can produce maps at any size up to 36 by 48 inches to fit a user's needs. These maps can depict an entire community or a portion, such as a village or a historic district. Also, because all layer information is stored by coordinate location, it is easy to combine layers even if their sources are at different scales. However, the user must be careful about mixing together inappropriately scaled information. When combining layers of different source scale it is important to list all disclaimers related to accuracy.

Summary

We now have the ability to manage the map as a database rather than a picture. Spatial analyses that were inconceivable or impossible before are now possible and often relatively straightforward. New information can be created by interpreting information within one layer or by combining layers in any way desired.

- In a GIS, spatial information is stored in separate layers.
- Each data layer is registered to earth coordinates.
- Each layer consists of spatial features, each linked to a wealth of descriptive data via a unique ID.
- Because spatial information is stored digitally, it is readily manipulated and updated.
- Using GIS, maps and other hardcopy output can be easily customized to fit users' needs.

References

Archer, H. and P.L. Croswell. 1989. Public access to geographic information systems: an emerging legal issue. Photogrammetric Engineering and Remote Sensing, 55(11): pp. 1575-1581.

GIS World, Inc. 1989. *The GIS Sourcebook.* Ft. Collins, CO.

Marble, D.F., H.W. Calkins, and D.J. Peuquet. 1984. *Basic Readings in Geographic Information Systems.* SPAD Systems, Ltd., Williamsville, NY.

Office of Geographic Information Services, 1989. *Vermont Geographic Information System—GIS Needs Determination: Final Report for Phase I of Vermont's Comprehensive GIS Strategy Study.*

Office of Geographic Information Services, 1989. *Vermont Geographic Information System Conceptual System Design: Final Report for Phase II of Vermont's Comprehensive GIS Strategy Study.*

Tomlinson, R.F. and A.R. Boyle. 1987. The state of development of systems for handling natural resources inventory data, in *GIS for Resource Management: a Compendium.* Edited by W.J. Ripple. ASP & RS and ACSM, Falls Church, VA.

Chapter 4 GIS in Vermont

An understanding of the evolution of GIS activity in Vermont, and the institutions that have been established to support and direct it, will be helpful to communities seeking to take advantage of this new technology. Communities will need to know where to turn for locating services and data. They will want to avoid duplication of effort regarding data acquisition and developing standards and procedures. They will also want to take advantage of the public resources available to them from regional planning commissions, the University of Vermont (UVM), and the Office of Geographic Information Services (OGIS). Familiarity with the institutional framework that exists within the state will enable communities to interact more effectively with state agencies and RPCs in developing local databases.

GIS History and Rationale

Vermont's involvement with GIS dates back to the late 1970s when the School of Natural Resources at the University of Vermont began to build a GIS oriented toward natural resources management. In developing an extensive database for three Vermont counties, they began to appreciate its potential as a planning tool. A number of communities began to seek assistance from UVM, building up broad-based support for the GIS effort.

In 1988 the Governor's Commission on Vermont's Future concluded that GIS would be an important tool to assist communities and regions in planning for the future. The governor took the commission's recommendations on growth management, and proposed legislation to integrate local, regional, and state planning efforts in a consistent manner. A statewide, intergovernmental GIS was a key part of the proposal.

After the legislation passed in 1988, the Secretary of Administration was charged with overseeing the implementation of the plan to develop a Vermont GIS (VGIS). A fifteen member Policy Oversight Committee sought proposals for the development of an implementation plan. At the same time, five pilot projects were initiated by two regional planning commissions and one city. The planning study involved a needs survey and resulted in a prioritization of data needs and a catalog of existing data sources. Subsequently, the oversight committee decided that data layers designed to address local planning needs should receive the highest priority.

Organizational Framework

Office of Geographic Information Services

In June of 1989, the OGIS was established within the Agency of Administration to act as the facilitator of GIS activities within Vermont. The mission of the OGIS is to coordinate the collection and recording of geographic data, to verify that data meet standards, and to disseminate data to GIS service centers and other users. Specifically the duties of the office are to

- provide or ensure provision of geographic information services, products, and support to regional and municipal planning commissions, and state agencies;
- make available services and data to others at rates established by the director;
- develop procedures for users to obtain access to and services from VGIS;
- develop and publish VGIS standards;
- ensure accuracy of VGIS data;
- coordinate acquisition of aerial photography,
- prepare a five-year plan;
- consult with the advisory board on policy;
- coordinate budgeting for GIS activities within state government;
- enter into memoranda of understanding (MOU); and
- prepare an annual report for the legislature.

OGIS has developed in concert with its Advisory Board a *VGIS Policies, Standards, Procedures, and Guidelines Handbook.* The handbook provides the basic guide for the management and operations essential to ensure the success of VGIS. The current table of contents is illustrated in Figure 4-1. A separate *Data Catalog* describes all the current data available through OGIS and other data providers. Subscriptions to these two documents can be obtained by contacting OGIS.

GIS Advisory Board

At the same time the OGIS was established, a fifteen member GIS Advisory Board was also established. Members representing, communities, RPCs, state agencies, the legislature, UVM, and private

Policies, Standards, Guidelines, and Procedures Handbook

VERMONT GEOGRAPHIC INFORMATION SYSTEM
HELPING VERMONTERS VISUALIZE CHOICE

Vermont Geographic Information System

PART 1 - POLICIES	
A. Regional and Local Government Roles	11/89
B. Public Access-Interim	9/90*
C. Pricing of Data, Information Products, and Services-Interim	9/90*
PART 2 - STANDARDS	
A. Digitizing Data	9/89
B. Map Coordinate System	9/89
C. Land Cover/Land Use Codes	10/90*
D. Data Layer Documentation	10/90
E. Community Codes	10/90
F. Land Survey Control Monumentation	1/91*
PART 3 - GUIDELINES	
A. Property Mapping	10/90
B. System Hardware Aquisition	10/90
C. Hardware and Software Configurations	11/90*
D. Attribute Definitions and Codes	10/90
E. Directory Structure and File Names	10/90
F. Maintaining an SML Library	12/90*
G. System Development and Maintenance	12/90*
H. Data Interchange	6/91*
PART 4--PROCEDURES	
A. Data Aquisition	10/90
B. Formats for Data Distribution	10/90
C. Pricing Schedule	10/90
PART 5--GLOSSARY OF GIS TERMS	

* Estimated

Figure 4-1. The table of contents of the "Policies, Standards, Guidelines, and Procedures Handbook" being developed for the Vermont GIS.

industry meet on a regular basis. The following are responsibilities of the Board:

- review OGIS policies for compliance to state law;
- advise the director on standards and policies;
- review the fee schedule and license procedures for GIS data distribution;
- review GIS data, plans, and activities of state agencies;
- review the five-year Vermont GIS workplan; and
- advise the director on proposed memoranda of understanding and cooperative agreements.

The board has adopted one policy—"Regional Planning and Local Government Roles", and two GIS standards—"Digitizing Standard" and "Map Coordinate System". Issues of data ownership, access, and pricing will be more fully addressed in 1990.

University of Vermont

The GIS facility within UVM's School of Natural Resources is expected to continue its role in research and development, and instruction. As more RPCs become GIS service centers (see below) and more in-state contractors are qualified to provide GIS-related services to communities, UVM will devote less effort to data conversion and the provision of routine services.

Regional Planning Commissions

The twelve regional planning commissions (RPCs) will be responsible for data management and development, and for applications development to support their own needs. Additionally, the RPCs are encouraged to become *Regional GIS Service Centers* to provide for the needs of communities within their jurisdictions when requested. This is because the costs involved in establishing a GIS facility at the community level are prohibitive for most Vermont municipalities. Regional service centers will be the intermediary for most GIS interactions between the state and communities. They will be the conduit for getting local and regional data into the VGIS. The roles of these service centers will include the following:

- providing GIS maps and analyses for communities which do not have in-house GIS capabilities;
- providing supplemental data and assistance to those communities with a GIS capability;

- serving as the coordinator and repository of digital data for the region's communities; and
- advising communities on how to meet VGIS data standards, and, where feasible, convert community data to digital form.

As regional coordinator for digital data, a Regional Service Center will collect local and regional data, check it against published minimum standards, and maintain a catalog for public reference. Subject to license agreements, it can distribute data prepared by the state or itself to any community requesting it. The Regional Service Centers will also be expected to engage in training and community education.

Some funding will be available to regional GIS service centers from state GIS funds, but not enough to support the GIS function entirely. The centers will need to charge user fees and find other means of cost recovery.

Table 4-1 shows the status of VGIS Regional Service Centers. A list of regional planning commissions, their addresses, and telephone numbers is provided in Appendix 4.

Table 4-1.VGIS Regional Service Centers

Currently in Operation
Chittenden County Regional Planning Commission
Central Vermont Regional Planning Commission
Franklin-Grand Isle Regional Planning & Development Commission
Lamoille County Planning Commission
Rutland Regional Commission
Two Rivers-Ottauquechee Regional Commission
Upper Valley - Lake Sunapee Council

Planned for Second Half of 1990
Northeastern Vermont Development Association
Bennington County Regional Commission
Windham Regional Planning & Development Commission

Planned for 1991
Addison County Regional Planning & Development Commission
Southern Windsor County Regional Planning Commission
Source: Vermont OGIS - June 5, 1990

Local Government

As was mentioned above, local planning needs are the primary focus of VGIS database development in the early phases. However, few communities will have the level of need or funding to warrant the development of in-house GIS capabilities. They are encouraged to seek the services they need from their Regional GIS Service Center if it has been established, or from the OGIS, UVM, or private consultants, if it has not. Assessing the level of GIS needs will be addressed in the next chapter.

The overall VGIS effort will depend increasingly on communities for local database development and local information management. As funding levels permit, OGIS, along with the RPCs, will continue to develop basic data layers for use at the community level (parcel boundaries, road centerlines, etc.) but the bulk of local database development will depend on the cooperation and efforts of Vermont communities. Neither the state nor the RPCs can supply the detail and frequent updates that local planning will require.

Data layers that communities will want to manage closely include the following:

- parcel boundaries,
- political and administrative boundaries,
- zoning,
- land use,
- infrastructure,
- septic systems,
- wetlands,
- surface water, and
- floodplains/floodways.

Communities may also develop data layers for their own use that will not become part of the VGIS (e.g., permit information). A significant local investment has gone into creating the local grand list and, in many communities, tax maps. These two databases are highly valuable to local planners and listers.

Some funds are available from the OGIS and from the Department of Housing and Community Affairs in the form of Special Planning

Grants for database development and other local GIS activities (see Appendix 6).

Other State Agencies

Three other state agencies—Development and Community Affairs, Natural Resources (ANR), and Transportation—are actively involved in the VGIS. Each is responsible for converting its existing files into an ARC/INFO compatible format and for acquiring and maintaining in that format new data that support agency activities. The OGIS and ANR have developed a prototype browse system which allows users to quickly determine from the computer what ANR data sets are available for a particular geographic area of interest (Figure 1-2). Communities should consult the OGIS or its draft *Vermont GIS Data Catalog* to learn what databases are available from the various state agencies.

Summary

- The Vermont GIS has its origins in planning legislation passed in 1988.
- The OGIS and an Advisory Board were established in 1989 to coordinate GIS activities, develop policies, and establish standards within the state.
- Because of the cost of GIS installations, it is expected that most communities will turn to their regional planning commissions or to consultants to provide GIS services.

References

Healy, D. 1989. Vermont's GIS: development to implementation. LIS/GIS Conference, November 1989, 9 pp.

Vermont Office of Geographic Information Systems. 1989. *Vermont GIS Policy #1: Regional Planning Commission and Local Government Roles.*

Vermont Office of Geographic Information Systems. 1990. *Annual Report to the Legislature: Vermont Geographic Information System.*

Chapter 5 Acquiring GIS Capabilities

The types of GIS capabilities needed by a community will depend upon several factors, the most important of which are population, the geographic size of the community, and the rate of change in land use experienced by the community. This last is probably most often felt in the form of development pressure. This chapter provides suggestions on how to assess community needs for geographic information management, and whether GIS is an appropriate data management tool considering these perceived needs and the financial and human resources available to the community. Further, it outlines the available options for fulfilling these needs.

Evaluating Mapping and Data Needs

What kind of GIS capabilities does your community need? Do you need better maps? Should you invest in hardware, software, training, etc? How do you decide? What's the next step?

To answer these questions the community needs to evaluate how it uses geographic information now and how it anticipates using it in the future. It also must take stock of what maps and databases it has in hand or has access to through regional or state sources at the present time. The community must realistically evaluate the capabilities and resources it can marshall including personnel, budget, and existing computer resources. These three areas must be appraised, in terms of both the present situation and future developments.

Community GIS Committee

The Regional Planning Commission (RPC) can provide a great deal of guidance to communities at this stage and should be consulted frequently. However, a GIS committee within the community needs to be authorized to take charge of this evaluation. This could be the planning commission, a subcommittee of it, or an ad hoc GIS committee. The community GIS committee should be large enough (at least three members) to divide up the work load. Town departments with significant mapping and data needs should be represented on the committee; these would likely be the Planning Commission, the Zoning Commission, public works department, and/or the lister.

A preliminary survey of municipal departments and other potential GIS users should be carried out to determine if there is interest in GIS. If the survey results indicate that there is both need for and interest in GIS at the local level, it would be appropriate to organize an informational session for selected community representatives to provide an orientation to GIS concepts and applications. This could be a half-day workshop presented by RPC staff, UVM staff, or by a private GIS consultant. Generating a list of local government tasks that involve spatial information (such as that presented in Chapter 1) would be one useful exercise to attempt in this workshop. Such a list would help in the next step, the design of a formal needs assessment.

If interest and enthusiasm is sustained through the workshop stage, then the community should embark on a formal needs assessment. Again, it may be wise to take advantage of a consultant's or RPC's expertise to guide the committee through this process. Chapter 6 describes the GIS needs assessment process and how the results are used in designing a database. For the purposes of this chapter, the fictional Town of Champlain, Vermont is depicted as an example of how a typical Vermont community might evaluate its GIS needs.

The Town of Champlain, with a population of 8000, is experiencing a moderate amount of development pressure. Traffic, parking, school enrollment, and the threat of accelerated strip development are all issues in the town. The Planning Commission is actively engaged in re-writing the Municipal Plan and wants to include physical constraints and infrastructure considerations in their efforts to concentrate development in the villages. The community will need both updated standard map products and customized maps and reports. Maps are needed for display at public meetings and hearings and as working documents for commissions, the Public Works Department, etc. There is a town planner who has a great deal of interest in, but no experience with GIS technology. The town offices have several computers and a few data files, but as yet, there is no direct sharing of files. The Regional Planning Commission expects to be up and running as a regional GIS service center within the next year and a half.

A three-member GIS Committee was appointed by the board of selectmen. The members represent the Planning Commission, the Public Works Department, and the Conservation Commission.

With the aid of the Regional Planning Commission, the GIS Committee conducted a preliminary survey, held a half-day GIS workshop for town officials, and conducted a formal GIS needs assessment. The detailed results of the needs assessment are discussed in Chapter 6. The highest priority data layers were determined to be town boundaries, parcel boundaries, soils classifications, and road centerlines at a scale of 1:5000. Of secondary importance is infrastructure information such as road and bridge conditions, water lines, and sewer lines which will be needed both at 1:5000 scale for town-wide coverage, but also at 1:1250 scale for more engineering detail in two village areas.

Champlain expects to have the town boundaries and parcel boundaries provided by the Vermont OGIS within the year. Soils data, converted by UVM from SCS soil surveys, will also be available within the year.

What are the Options?

The Town of Champlain, like all Vermont communities, has three basic ways it can acquire GIS capabilities:

- develop an in-house facility,
- rely on a service center such as the RPC or UVM, or
- contract with a private consultant.

The most flexible approach may often be a combination of these three approaches.

Option 1: Develop in-house capabilities

The minimum requirements for an in-house capability are a computer system (hardware and software), data, trained staff, adequate space, and an operations budget. It should be well understood in the community that this is a long-term commitment as results will not come quickly at first and the database has value only if it is maintained and updated regularly.

Purchasing Hardware and Software

The selection of hardware and software should occur in tandem because some software packages perform adequately only on certain hardware platforms. There are many GIS software packages on the market today, each with its own strengths and weaknesses. ARC/INFO was selected as the state standard because of its powerful analytical abilities and because it is available in mainframe, workstation, and PC versions. Worldwide, it is the most commonly used GIS software package.

GIS World, Inc. conducted an industry-wide survey which provides a good starting point for a community wanting to look beyond the ARC/INFO software adopted as the Vermont standard. The survey provides information on general system characteristics, computing environment, number of users, pricing, data structure, database management, and system functional characteristics for 62 software packages. Addresses and phone numbers of the various vendors are included.

The following key questions should be addressed when selecting hardware:

- What hardware supports the preferred software?

- How many users will be accessing the GIS database?
- To what extent will information be shared among multiple users?
- What performance speeds are required to meet productivity objectives?
- What will be the ultimate size of the database?
- Will the system need to handle vector or raster data or both?
- What price/performance advantages does each alternative offer?
- How will the system expand to accommodate new users or applications over time and what are the implications for configurations?
- Will a centralized or distributed configuration be better suited to the community's operational environment?

If proposals are to be solicited from vendors, it is essential that a clearly specified set of evaluation criteria be developed so that both the GIS Committee and vendors have a clear understanding of what is requested and required. These same evaluation criteria should be incorporated into the specifications used for conducting benchmark testing if, in fact, the size of the procurement warrants the level of effort required to conduct benchmarking. Current technical specifications for hardware are available from OGIS.

Undoubtedly, as the evaluation of candidate systems proceeds, advocates for each will emerge. However, it is important for the community GIS Committee to keep in mind that data—collecting it, converting it, maintaining it, and designing the database—is estimated to comprise anywhere from 65 to 90 percent of the GIS implementation costs. Therefore, considerably more effort should be devoted to database design and the procedures associated with data maintenance and dissemination than to the technology involved.

A community's existing computer hardware may be adequate to support a GIS software package and considerable savings can be achieved if this is the case. However, reaching this conclusion requires careful consideration to avoid a band-aid approach or expecting antiquated or underpowered hardware to efficiently run state-of-the-art software. The list of questions provided above and the description of GIS hardware and software requirements provided in Appendix 3 should be applied to an evaluation of the community's existing computer hardware and software.

Personnel

Experience with GIS pilot projects in Vermont has shown that there must be at least one person assigned full time to successfully operate a GIS installation. It should be emphasized that this is a minimum. Ideally, the system operator will have a background in planning, mapping, computer science, and/or related fields. Beyond that, the individual will require formal training in the specific software being used. This may take one to three weeks. If training is to be on the job, allow for six to nine months of full-time experience with the system before the operator is expected to be proficient. GIS operators and managers will need further training opportunities (e.g., conferences, workshops, short-courses) on a periodic basis in order to stay current in the field.

The community must decide whether they can afford indefinitely the minimum of one full-time operator. GIS professionals are currently in great demand throughout the United States, and, accordingly, can command high salaries. A trained GIS operator can probably command a salary of $30,000. Turn-over can be a significant problem because once an operator is proficient with a system, his or her marketability has increased.

Once a local GIS installation has become functional, most communities will find it desirable to have at least two GIS staff members: the full-time operator and a manager devoting at least half-time to such issues as policy, maintenance, scheduling, access, contracts, etc.

The community must decide whether existing personnel can assume the role of GIS operator or whether additional personnel must be hired. The capabilities and time commitments of potential candidates already on the municipal payroll must be assessed to determine whether additional responsibilities are realistic. Additionally, the candidate should be enthused about GIS since training is lengthy and results can be long in coming. The GIS committee should also weigh the expense of hiring new staff that is already trained versus providing training (either on the job or formal) for existing staff.

Space

Suitable offices will need to be established to house the GIS installation. The basic configuration shown in Figure 3-8, consisting of a microcomputer, desktop printer, pen plotter, and digitizing tablet requires a minimum of 150 square feet of office space. The office needs to be secure and have a reliable electrical power supply. Temperature and humidity should be well regulated since changes in these greatly affect paper maps. Maps should be stored flat—ideally, in map case drawers. Good light and comfortable chairs are needed for working at the computer, especially during digitizing and map preparation. Several large tables should be available for drafting and map compilation.

Budget

The budget for a GIS facility includes both capital expenditures for acquisition of hardware and software, and operational expenditures including salary, hardware maintenance, software support, supplies, and data acquisition, and possibly office rent.

Capital Budget - hardware and software

The basic configuration illustrated in Figure 3-9 has the following estimated costs (based on 1990 prices):

Microcomputer	$4,500
Pen Plotter	6,000
Digitizer	5,000
Printer	500
Software	4,500

If the community wants a dial-up connection to the RPC, OGIS, or UVM for file transfer, a modem will be needed. Prices for modems are based on their rate of transmission:

2400 BAUD	$150
4800 BAUD	400
9600 BAUD	750

Annual Operations Budget

salary (one full-time GIS operator)	$25,000 - 30,000
software support	1,000 - 1,500
hardware maintenance	500 - 1,000
purchase of data layer	
road centerline data	1,200 - 2,000
land use data	2,000 - 4,000
office space rent (150 sq. ft. minimum)	variable
materials	600 - 900

The figures provided for acquisition of data layers are very rough estimates. Depending upon the level of in-house expertise, a community GIS facility might save money by developing a data layer in-house. On the other hand, there are GIS consultants and data conversion houses that specialize in database development which can provide efficiencies and economies that are rarely achievable in a small GIS operation. Regardless of whether data conversion is performed in-house or by a consultant, the time and expense involved in developing a data layer depends heavily on the quality of the source materials. For example, computerizing an accurate and useful parcel layer will be extremely expensive if the existing parcel (or tax) maps are not drafted on a controlled base.

The amount to be budgeted for office space will vary in each community. Some communities will have suitable space available in their municipal offices. Others will have to pay the local market rate for rental space.

The amount to be budgeted for materials will vary widely depending upon how busy the GIS facility is and how many hard copy maps and reports it will be producing a year. Materials are likely to include plotter paper and mylar, drafting pens, pencils, tape, computer diskettes, and cartridge tapes.

This option requires a very serious commitment on the part of the local elected officials. Communities should not set in-house GIS capacity as a goal unless they have thoroughly evaluated start-up costs, annual staffing, and space requirements.

Vermont communities may be eligible for planning grants and other state monies for planning, mapping, and GIS services (see Appendix 6).

Option 2: Rely on service center - RPCs or UVM

As of summer 1990, seven Vermont Regional Planning Commissions (RPCs) have become operational as VGIS regional service centers prepared to assist communities in their regions with their GIS and mapping needs (Table 4-1). Three more regional service centers should be operational by the end of 1990 and the remaining two in 1991. The regional service centers are to supply GIS assistance on a fee-for-services basis. They will coordinate data collection within their region and verify that collected data meets VGIS standards before entering it into the database. For those communities desiring it, they will be able to provide training, automate data, perform analyses, and create maps and reports. Fee structures, funding from the state, cost reimbursement, and methods for assigning priorities to services requested have yet to be established. Work agreements may be authorized through contracts and/or memoranda of understanding (MOUs). RPC staff are generally available for telephone consultation.

The University of Vermont (UVM) GIS staff have pioneered GIS applications in Vermont. Running on a large mainframe computer, UVM's version of ARC/INFO has capabilities and efficiencies not to be found in microcomputer-based systems of the RPCs or the in-state private consultants. UVM GIS staff are generally available for telephone consultation. UVM provides GIS assistance on a fee-for-services basis including training, database design, data automation, analysis, and map and report production. However, because UVM facilities are heavily used for teaching, research, and for large state contracts, the availability of staff and computer time for smaller projects may be limited.

Middlebury College, Johnson State, Lyndon State, and Vermont Technical College (Randolph) now include GIS in their curricula and are building their GIS capabilities.

Option 3: Contract to consultants

There are a number of private contractors in Vermont and surrounding states that offer GIS and related expertise on a fee-for-services basis. Several of these have ARC/INFO running in-house by experienced GIS professionals. These contractors include planners, surveyors, engineers, mapping firms, data conversion firms, computer vendors, and forestry and other consultants. OGIS maintains a list of these private contractors (see Appendix 8). Any GIS, mapping, or related service or product can be acquired through these contractors, including needs analyses, project and database design and implementation, data conversion, spatial analyses, map and report production, and basic orientation and training seminars.

Of particular interest may be the firms that specialize in mapping and data conversion. Most have multiple shifts, experienced staff, and specialized hardware and software resulting in greater efficiency and consistency than most communities could hope to achieve in-house.

The OGIS and the RPCs can help communities draw up requests for proposals (RFPs) and contract specifications to use when contracting for GIS-related services.

Selecting the Appropriate Option

Choosing among the options described above revolves around the kinds of services a community needs, how frequently they need them, and whether it has the resources (described above under Option 1) and can make the commitment to develop in-house capabilities. The following series of questions can provide a helpful framework for choosing the best option:

1. **Are the community's geographic information needs adequately met?** [If no, see 2]
2. **Would GIS capabilities improve the situation?** [If yes, see 3]
3. **Would GIS capabilities be used on a frequent (e.g., at least weekly) basis?**
   a. If the answer is no, then it is clear that there is no need to develop in-house capabilities. However, the community will

probably want to investigate the relative merits of consultants, the RPC, and UVM. [See 4]

b. If the answer is yes, the GIS Committee must determine whether the community is willing and able to make a sustained commitment to developing a GIS facility in terms of staff and budget. Commitment?

(1) If the answer is yes, the GIS Committee should proceed with detailed implementation plans.

(2) If the answer is no, the relative merits of consultants, the RPC, and UVM should be determined. [See 4]

4. Will mainframe capabilities be required?

a. If yes, the community will need to turn to UVM or an out-of-state consultant. As of spring 1990, no in-state consultant or RPC is running GIS software on a mainframe computer.

b. If no, again the relative merits of consultants, RPCs, and UVM would have to be considered. [See 5]

5. Is the RPC up and running as a GIS service center?

a. If no, the community will need to turn either to UVM or a consultant.

b. If yes, compare consultants, UVM, and RPC.

From this exercise, it is clear that the bulk of communities' GIS needs can be met by UVM, the RPC, or a consultant, or a combination of the three. In evaluating a GIS organization's expertise, the community should review the following criteria:

- capability and adequacy of personnel,
- relevant experience,
- ability to furnish service and support,
- cost of services,
- consultant's approach to requirements,
- proposed time frame for delivery of products,
- compatibility/interface with community's existing hardware/software,
- capabilities of systems and software,
- experience with local governments,
- consultant's current and projected work load,
- geographic location,
- consultant's statement of qualifications,

- quality, extent, and location of training (if requested), and
- quality of presentation/demonstration.

Conducting a pilot project is often a good way for a community to gain hands-on experience with GIS. No matter which option is ultimately selected, the community will gain a greater understanding of GIS capabilities and limitations and how it will fit within the existing organizational structure. Pilot projects yield useful information on production rates, memory and storage requirements, and the response of users to GIS products, and should suggest the direction in which the community should proceed.

Combination Approach

After studying their situation and the available options, a community may decide that their GIS needs will be met best through a combination of basic in-house capabilities, assistance from a service center, and contracted services from a consultant. This is perfectly feasible as long as VGIS standards are adhered to and responsibilities are clearly spelled out. Again, the imaginary Town of Champlain is used to see how this approach would work.

Several data layers will be available to Champlain before it or the RPC have a means of handling it. Their plan is to utilize a private contractor in the short term, then rely on the RPC when it becomes a functioning GIS service center, and perhaps, as needs arise in the more distant future, acquire some in-house capabilities themselves. Town boundaries, parcel boundaries, and road-centerlines will be available within the year from OGIS. Soils data is already available from UVM. As a first step, Champlain will hire a consultant to build a database for them, consisting of these layers plus a surface waters layer. Over the next two years, the infrastructure information will be compiled and drafted at the two desired scales (1:5000 and 1:1250) by Champlain's Public Works Department with guidance from the consultant. Then the consultant will automate both the maps and the attribute files associated with them. The consultant will provide a base map, a soils map, and a base + infrastructure map to assist the Planning Commission in their Municipal Plan update.

When the RPC is up and running, the Champlain database will be transferred and the RPC will become the custodian, performing updates and producing maps and reports as needed. The Town of Champlain will continue to compile new maps and data (e.g., historic sites, land use) under the guidance of the RPC and submit them to the RPC for automation. When the town budget permits, Champlain plans to buy their own computer with at least the ability to perform queries and create maps and reports.

Summary

- To determine how involved with GIS a community should become, it needs to evaluate how it uses geographic information now and how it would like to use it in the future.
- A community GIS committee should be appointed to perform a GIS needs assessment, to serve as liaison between the planning commission and providers of GIS services, and to oversee any GIS related activities the community undertakes.
- The options available to Vermont communities for acquiring GIS services include:

  - developing an in-house facility,
  - relying upon a service center (RPC),
  - contracting with a private consultant, or
  - some combination of these.

- To choose among the options, the GIS committee must evaluate the kinds and frequency of services the community needs, the personnel and budgetary resources available, and whether the community is prepared to make a sustained commitment to GIS activities.

References

GIS World, Inc. 1989. *The GIS Sourcebook*. Ft. Collins, CO

Goodchild, M.F. and B.R. Rizzo. 1987. Performance evaluation and workload estimation for geographic information systems. International Journal of GIS 1(1): 67-76.

Guptill, S.C. 1989. Evaluating geographic information systems technology. Photogrammetric Engineering and Remote Sensing 55(11): 1583-1587.

Levinsohn, A.G. 1989. A strategic planning based approach to the design of land information systems. Proceedings of the 1989 URISA Annual Conference, Vol. 2, 30-38.

Montgomery, G.E. 1989. Guide to project implementation. in *The GIS Sourcebook*. GIS World, Inc. Ft. Collins, CO.

Vermont Office of Geographic Information Services. 1989. Conceptual System Design: Final Report for Phase II of Vermont's Comprehensive GIS Strategy Study.

Wentworth, M.J. 1989. *Implementation of a GIS Project in a Local Government Environment: The Long and Winding Road*. Proceedings for the 1989 URISA Annual Conference vol.2:198-209.

Chapter 6 Database Design

It is the information that resides in a geographic information system—its quality and organization—that ultimately determines the utility of the technology to planners and local officials . The organization of information within the GIS is so important in determining utility that it merits a separate discussion of its own. Therefore, this chapter focuses on how to determine what kinds of data should be included in a GIS database and how to organize the database. Most communities will not get deeply involved in database design, but an appreciation of the issues will help them work with providers of GIS services in developing and maintaining a useful community database.

The costs related to GIS data—collection and conversion, and designing and maintaining the database—are estimated to range from 65 percent to 95 percent of GIS implementation costs. Therefore, a community getting involved with GIS should dwell less on the technology, despite its allure, and more on the issues of data quality, organization, and maintenance. The design of the database, in combination with the available data sources, will determine which data conversion methods are most appropriate and, thus, the costs involved in creating (and maintaining) the database.

A well-thought-out database design with clearly defined and well-documented attribute data will be a boon to community planning and management. Analyses, as well as map and report production, will be versatile and logical. It will facilitate the process of automating data at the outset and maintaining consistency in methodology and classification during subsequent database updates.

Objectives

The objectives of database design are:

- to maintain data consistency and integrity,
- to reduce data redundancy,
- to increase system performance, and
- to maintain maximum user flexibility.

Data files should be easy to maintain, update, modify, and protect. The following factors influence database design:

- the data needs of the intended applications,
- the availability and format of existing data,

- size of the database,
- the number and sophistication of the users,
- the organizational structure of the users,
- update and maintenance procedures available,
- hardware platform/configuration,
- schedule,
- budget, and
- available management support.

Conducting a formal *needs assessment* is the best means of assessing the first four factors.

Needs Assessment

There are five phases to a *needs assessment:*

- identify potential users,
- identify their output product requirements,
- define spatial data categories,
- establish the required level of accuracy, and
- evaluate data sources for quality and suitability.

Identify potential users

To start the needs assessment, the community GIS Committee (described in the previous chapter) must determine those who are potential GIS users (and contributors) within the community. Who has data sets that would be appropriate for inclusion in the database? Who would benefit from creation of a GIS database? In addition to participants from within the community, involvement of officials from surrounding communities, the regional planning commission (RPC), and the state should be considered. Care and thoughtfulness are needed on this issue so that potentially important contributors to, and supporters of, a GIS project will not be overlooked.

Identify output product requirements

Through an interview process and/or by distributing questionnaires, the committee must determine the following for each user:

- data needs,
- positional accuracy requirements,

- output product requirements,
- how the products are to be used, and
- who the data comes from and goes to.

A questionnaire such as the "Data Needs Questionnaire" presented in Figure 6-1 addresses these first two items, and can be used as a model by communities embarking on a GIS needs assessment.

Define spatial data categories

A step that may prove useful in organizing the results of the user survey is constructing a matrix of data items versus data users. Figure 6-2 presents a portion of the results from the Town of Champlain's user survey in such a matrix. Items needed by many users should receive a high priority when building the database. For example, from Figure 6-2, we can see that the road network and town boundaries will be needed by all users, while elevation and information on sewers will be used by relatively few.

It should be emphasized that the number of users requesting a given data layer may be only one of several criteria used when assigning priorities to data layers. Other criteria may be availability, cost, and importance of the data layer in terms of safety, legislative mandates, or resulting fiscal savings for the town.

Creating another matrix, data items versus standard output products, such as the one shown in Figure 6-3 for the Town of Champlain, can help to organize the seemingly disparate needs of GIS users. It makes it possible to determine whether a few standard output products can adequately meet the needs of several users. For example, creating a town base map at 1:20,000 scale showing town boundaries, road centerlines, surface water, and elevation will be a valuable first step toward meeting the needs of many of the Town of Champlain's users. Using this standard product, the various users can customize maps and files for their own purposes. Eventually, their data can be incorporated into the GIS. For example, the school board can use the 1:20,000 scale base map and draw in district boundaries and bus routes. Similarly, the town tree committee can inventory tree locations on the base map.

When a new item of spatial or attribute data is to be added to the database, consult the users of that item to ensure that it is defined properly. For example, a traffic engineer will require traffic counts and other data recorded in a specific format with a certain degree of positional accuracy. Entering data in a format that doesn't meet a user's needs is a wasted effort. Similarly, consult the RPC or the OGIS

Figure 6-1 : Data Needs Questionnaire (based on a survey form developed by GIMS, 1989).

Name:____

Committee or Group:________________________________Telephone:______________

From the following list, select the map features (map information) used by your committee or commission. Please note the ones you use NOW with "N" and the ones that you would like to use in the FUTURE with "F". Also indicate the amount of positional accuracy required. If positional accuracy is not important or if you are not sure of the level of accuracy required, just use "N" or "F" alone.

Example: N-2 means NOW with +/- 2 foot accuracy, OR F-5 means FUTURE with +/- 5 foot accuracy

ROAD NETWORK
____centerlines
____names
____rights-of-way
____edge of pavement
____pavement types
____bridges
____culverts
____traffic controls
____curb and gutter
____parking facilities
____safety features
____other

NATURAL FEATURES
____soils
____slopes
____water bodies
____aquifers
____wetlands
____vegetation
____wildlife habitats
____endangered species
____other

GEOLOGIC FEATURES
____surficial materials
____minerals
____bedrock structure
____faults and fractures
____other

LAND USE
____ residential
____ commercial
____ industrial
____ institutional
____ agricultural
____ transportation
____ recreational
____ cemeteries
____ fencelines
____ other

ADMINISTRATIVE
____political boundaries
____national forests
____state land
____school districts
____fire districts
____zoning districts
____other

ROUTES
____public transportation
____school bus
____snow plow
____other

UTILITIES
____manholes
____water mains

UTILITIES
____valves
____hydrants
____pumping units
____storage units
____meters
____sewer mains
____sewer service lines
____lift/pumping stations
____electrical lines
____electrical poles
____street lights
____substations
____transformers
____generating stations
____gas lines
____telephone lines
____telephone poles
____cable TV lines
____other

PARCELS
____parcel boundaries
____parcel dimensions
____parcel number
____parcel address
____owner address
____easements
____census tract
____subdivision name
____subdivision limits
____parcels in use value program
____public use parcels
____other

Please indicate, using a map or narrative, the limits of your present mapping coverage and indicate where you will need mapping in the future.

DATA USERS \ DATA ITEMS	TOWN BOUNDARIES	PARCEL BOUNDARIES	ROAD NETWORK	BRIDGES	CULVERTS	SEWER LINES	PARKING SPACES	TRAFFIC COUNTS	BUS ROUTES/STOPS	BUILDING DIMENSIONS	PERMITS	ADDRESS	CURRENT LAND USE	ZONING DISTRICTS	SCHOOL DISTRICTS	ELEVATION	SLOPES	SOILS	GEOLOGY	AQUIFERS	WATERBODIES	WETLANDS	FLOODPLAINS	FORESTS	TOWN TREES	UTILITY LINES	POPULATION (CENSUS)	ETC.
Selectboard Members	•		•	•		•							•	•	•						•							
Planning Commission	•	•	•			•		•	•		•		•	•	•		•	•	•	•	•	•	•	•			•	
Conservation Commission	•		•										•	•		•	•	•	•	•	•	•	•	•	•	•		
Zoning Board	•	•	•			•	•	•		•	•	•	•	•			•	•			•	•	•	•				
Town Clerk	•	•	•									•		•	•						•							
Listers	•	•	•									•		•														
Assessor	•	•	•			•				•	•	•	•	•														
Public Works	•		•	•	•	•	•	•	•												•	•	•		•	•		
School Board	•		•						•							•											•	
Economic Development Commission	•	•	•			•	•						•	•												•	•	
Recreation Committee	•		•							•			•				•				•			•				
Tree Committee	•		•			•															•	•			•	•		
etc.																												

Figure 6-2. A portion of the results of the Town of Champlain's User Needs Survey.

PRODUCTS \ DATA ITEMS	TOWN BOUNDARIES	PARCEL BOUNDARIES	ROAD NETWORK	BRIDGES	CULVERTS	SEWER LINES	PARKING SPACES	TRAFFIC COUNTS	BUS ROUTES/STOPS	BUILDING DIMENSIONS	PERMITS	ADDRESS	CURRENT LAND USE	ZONING DISTRICTS	SCHOOL DISTRICTS	ELEVATION	SLOPES	SOILS	GEOLOGY	AQUIFERS	WATER BODIES	WETLANDS	FLOODPLAINS	FORESTS	TOWN TREES	UTILITY LINES	POPULATION(CENSUS	ETC.
Parcel Maps 1:5000 scale	•	•	•																		•							
Town Base Map 1:20000 scale	•		•														•				•							
Zoning Map 1:20000 scale	•		•											•							•	•	•					
Development Suitability Map 1:20000 scale	•	•	•				•		•				•	•		•	•	•	•	•	•	•	•	•				
Public Facilities Map 1:20000 scale	•		•				•		•				•		•						•							
Engineering Maps 1:1250 scale	•	•	•	•	•	•	•	•			•															•		
Grand List	•	•										•																
Valuations	•	•								•	•	•	•	•														
Tree Inventory and Map	•		•																		•	•			•	•		
etc.																												

Figure 6-3. A portion of the results of the Town of Champlain's User Needs Survey.

to see if coding standards or conventions have been devised for the new data.

Establish required accuracy levels

One of the most difficult tasks in designing a database is determining the smallest map scale that will satisfy the accuracy needs of the majority of users. This is necessary because the cost of a mapping or GIS project is directly proportional to the accuracy level. Usually the cost of the most accurate, complete solution is unacceptable because of budgetary limitations. The job then, is to decide what is acceptable in terms of cost, technical limitations, accuracy, and the ultimate use of the database.

Most communities will find that working at a scale of 1:5000—the scale of Vermont's orthophotos—will satisfy their accuracy requirements for most data layers. This scale will be most convenient because of the availability of orthophotos and existing digital data layers at this scale. However, engineering and infrastructure layers may require far greater accuracy, and thus, larger scales. If scale and accuracy become an issue, the results of the needs survey can be tabulated to determine the most commonly required level of accuracy for a given data item in order to arrive at a minimum acceptable positional accuracy for the data item. This ensures that the database design is based on the most stringent accuracy requirements of the frequent users. If the issue can't be resolved satisfactorily, one solution may be to create a mini-database of those layers that require greater accuracy than the 1:5000 scale can provide.

Evaluate data sources

Potential GIS users should also be asked what maps, tables, and data files they can contribute to the community database. The questionnaire should ask for information on the scale and resolution of the data, how and when it was collected, from what source, how it is updated, and how it is stored. These results need to be compared with the list of priority data needs.

In addition to the issues of priority and whether the needed data is available in a particular form, the committee must evaluate the accuracy level and date of the sources and whether there is sufficient planimetric control. (The "rubber sheeting" capabilities of GIS have limitations.) Keep in mind the often quoted phrase "Garbage in, garbage out." Entering poor quality data into a computer and manipulating it will not improve its accuracy or basic suitability for the task at hand. If the existing information is not adequate, funds will need to be allocated to acquire the needed data. More will be said about data sources in the next chapter.

Database Structure

The needs assessment process has determined what data are to be included in the database and what data are available. Now a logical organizational structure must be devised for that data within the computer. That structure should be as simple as possible while still providing the flexibility to meet the majority of users' needs. A database with a wide variety of user views and applications should have more basic organization (i.e., more layers and attribute categories). If certain data items tend to be used together, they should be considered for inclusion in the same layer. Data that are maintained by different departments and that have security restrictions, or are frequently updated should be isolated into separate layers.

Data will be assigned to one of three database components:

- cartographic layers—spatial information,
- feature attribute tables—descriptive information residing within the GIS database, or
- look up tables—descriptive information residing outside the GIS database but linked to it by a relational item (see Chapter 3).

The design of the descriptive or tabular half of the database—both the feature attribute tables and the look up tables—is just as important as the design of the spatial half. The way the tabular data is organized into a relational database management system has a big impact on system performance. When structuring the attribute data, it is important to anticipate update procedures as well as uses of the data. The goal is to assign items to appropriate layers and to devise coding schemes and definitions that adequately describe those items.

How this would be done can be demonstrated using the results of the Town of Champlain's needs assessment shown in Figures 6-2 and 6-3. The first data layers to be entered into the 1:5000 scale database would be:

- political boundaries,
- parcel boundaries,
- surface water,
- road centerlines, and
- soils.

The structure of the database is diagrammed in Figure 6-4.

TOWN OF CHAMPLAIN
1:5000 scale database

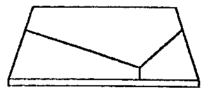
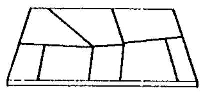
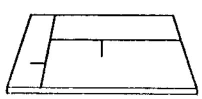
SPATIAL DATA	ATTRIBUTE TABLES	LOOK-UP TABLES
	town boundaries (polygon) feature ID	
	parcel boundaries (polygon) parcel ID	Town permit file Town grand list
	waterbodies (polygon) waterbody ID name class depth	
	waterbodies (line) stream segment name class	Town maintenance files
	road centerlines (line) road segmentID class surface type	
	soils (polygon) soil polygon ID soil type slope	SCS ag potential SCS engineering potential SCS septic potential

Figure 6-4. Database structure for the Town of Champlain's 1:5000 scale GIS database. Information will be stored either as spatial data or attribute data. Attribute data will be stored in Attribute Tables or in Look-up Tables residing outside the GIS but linked to it via feature IDs (adapted from Chambers, 1989).

The **town boundaries** have no description other than their positions so no attribute class definitions are needed. The attribute files contain only the feature ID, which is a unique identifying code that distinguishes this item from all others in the layer. Source and accuracy of the boundary lines will need to be included in the documentation for the layer.

The spatial data for **parcel layer** will reside in a polygon layer. Initially, the associated attribute file will contain only the parcel ID. At a later date, the community can add more tabular data to the attribute file in the GIS, or enter it in a look-up table that exists outside the GIS. If the parcel ID entered into the GIS is the same as the parcel number in the grand list, the grand list becomes a look-up table; its contents can be associated with the spatial information in the GIS.

Surface water information needs to be split into two sub-layers to be accurately represented at the 1:5000 scale: lines and polygons. A minimum mapping unit (see Chapter 9) must be defined to distinguish line features from polygon features, e.g., a minimum polygon size of 1/4" x 1/4". A pond smaller than this size would not be mapped (or would be relegated to a third, point layer). A pond or lake larger than this would be assigned to the polygon layer. A stream narrower than 1/4" would be included on the line layer. A stream or river wider than 1/4" would be included on the polygon layer. These criteria, along with any other information and definitions, must be spelled out in detail and included with the documentation that accompanies the data layer.

For each water body, the community wants to store three categories of attribute information besides the unique ID: name (e.g., Muddy Brook), class (e.g., Vermont Class A), and for ponds and lakes, maximum depth. A coding scheme needs to be assigned (e.g., 1 = Class A, 2 = Class B) and definitions and sources need to be recorded for this information (e.g., that water quality and depth information is from the Vermont ANR Water Quality Division and follows their class definitions).

The **road centerline** information will be a line layer. With the assistance of the public works director, the road network should be divided into segments so that descriptive information (e.g., maintenance history and eligibility for state and federal funding) can be accessed later. Initially, the community has only segment ID, road class, and surface type information in the attribute file. Roads will be coded as Class 1, 2, 3, or 4 as defined by the Agency of Transportation. Surface type will have a value of 1 to 6 as provided by the local department of public works. Again, the coding schemes and definitions must be documented. Always contact the agency that is the source of a data layer and the OGIS for the current attribute schema and codes.

Soils information will consist of a polygon layer available from SCS. Each polygon will have an ID, a soil type, and a slope. Eventually a series of look-up tables will be typed into a computer file so that the agricultural potential, engineering potential, and septic system potential associated with each soil type can be linked to the soil polygons via the polygon IDs. When this is accomplished, the Town of Champlain will be able to create GIS-generated maps showing the distribution of prime agricultural soils, poorly drained soils, soils with limitations for septic systems, etc.

Database Documentation

Documentation is necessary if users are to have confidence in the data and use it appropriately (e.g., not assume greater accuracy than is warranted). Codes, definitions, and sources cannot reside only in the heads of the database creators, since the database is expected to have a long lifetime. The documentation should include the following components:

- a comprehensive *data dictionary with descriptions of all items and codes for each layer,*
- diagrams and discussions of concepts behind the classification scheme,
- data sources for all layers and attributes, and
- implementation procedures including processing tolerances.

Ideally, the documentation should reside within the database and be available interactively to users. If this is not possible hardcopies should be made available to all database users. Figure 8-1 illustrates a typical document file that might accompany a data layer.

Pilot Study

The database design often requires some modification after it is tested under production conditions. This is why it is advisable to conduct a pilot study before embarking on extensive database development. A *pilot study* is the implementation of the database design over a limited geographic area, e.g., one orthophoto or one village. The pilot study helps GIS managers and clients

- test the database design,
- develop procedures for production tasks,
  identify obstacles to system implementation,
- develop specifications for data entry contracts, and
- gain support from management by providing timely results and products.

Summary

- The quality and organization of the data are the greatest determinants of GIS utility.
- Data collection, organization, automation, and updating comprise around 80 percent of the costs associated with GIS.
- The database structure is designed to
  - maintain data consistency and integrity,
  - reduce data redundancy,
  - increase system performance, and
  - maintain maximum user flexibility.
- The results of a formal user needs assessment provide the key to the design of a community's GIS database.
- A pilot study can be useful in testing the database design before full-scale implementation is attempted.

References

Chambers, D. 1989. Overview of GIS database design. *ARC News* 11(2): 17-21.

GIMS (Geographic Information Management System) Committee. 1989. Multi-purpose geographic database guidelines for local governments. Photogrammetric Engineering and Remote Sensing 55(9): 1357-1363.

Levinsohn, A.G. 1989. A strategic planning based approach to the design of land information systems. Proceedings of the 1989 URISA Annual Conference, Vol. 2, 30-38.

Vermont Office of Geographic Information Services. 1989. *Conceptual System Design: Final Report for Phase II of Vermont's Comprehensive GIS Strategy Study.*

White, R. 1989. Advantages, disadvantages, and costs associated with map creation methods, accuracy, and data base design. Proceedings of the 1989 URISA Annual Conference 1: 100-116.

Chapter 7 Building a GIS Database

We have discussed how to identify the information that needs to be included in a community's GIS database and how that information should be structured to provide maximum utility to users. This chapter describes the procedure for automating the data, i.e., how to convert it from its existing format—usually maps and paper files—to a format usable by the computer. This is the most labor-intensive and time-consuming aspect of GIS operation.

Data Sources

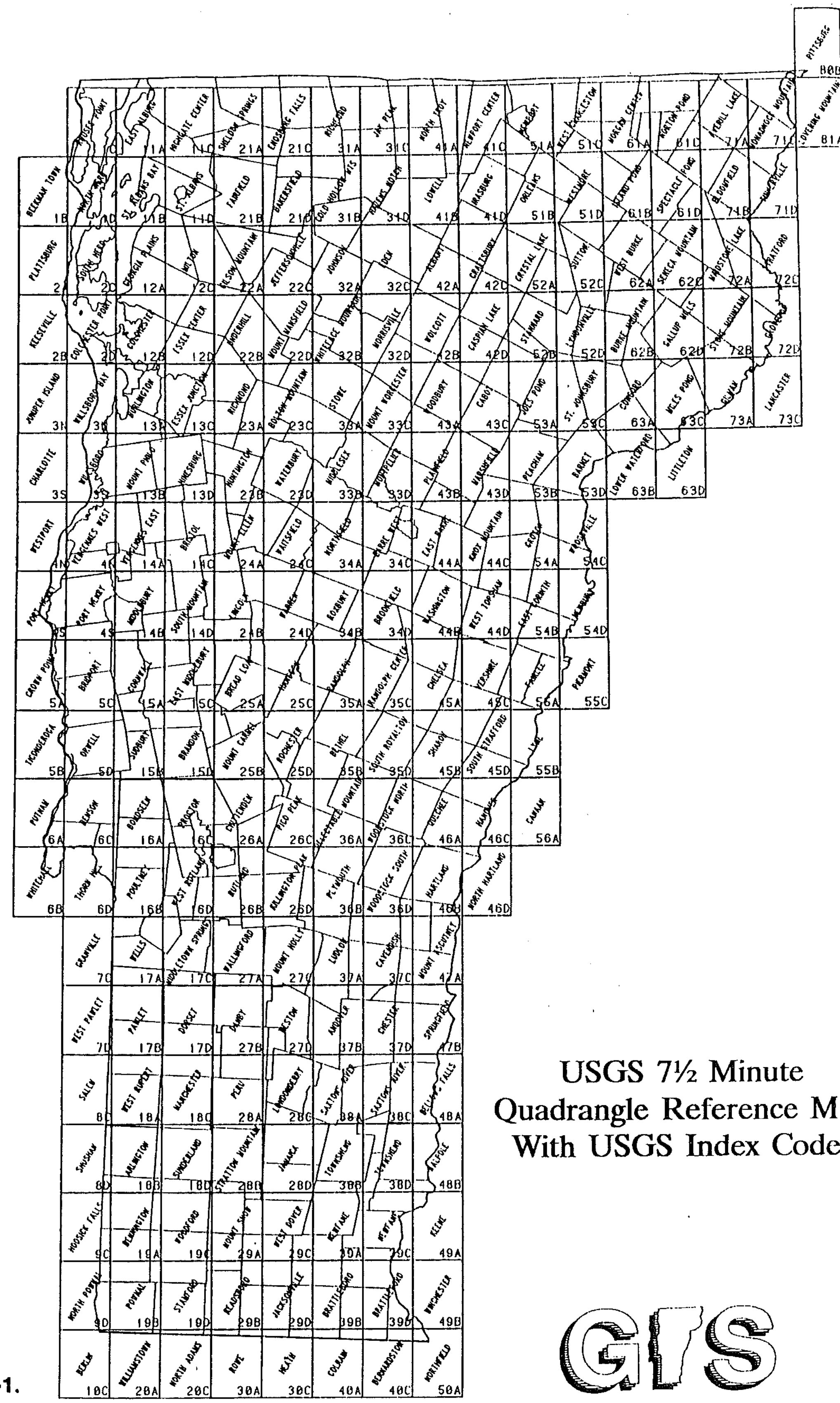
There are many possible sources for data suitable for inclusion in a GIS, including maps, aerial photographs and satellite imagery, tabular files, reports, and existing digital data. The goal of the data automation process is to convert the data from diverse existing formats to a common digital format. As we learned in Chapter 3, a GIS deals with graphic (spatial) and attribute (descriptive) information in a digital format. The information contained in the diverse data sources must be converted into this digital format.

Maps

The bulk of the information that a community will want to include in its GIS database will come initially from maps. These include USGS topo quads, town and state highway maps, tax maps, SCS soil maps, geologic maps, and engineering drawings.

The USGS $7\frac{1}{2}$ minute topographic quadrangles (*topo quads*) will provide a great deal of information for community inventories, despite their relatively small scale of 1:24,000 or 1" = 2,000'. The entire state of Vermont has been mapped at this scale. Some maps are very new (still in preliminary draft) while other are 30 to 40 years old. Each map sheet has a unique name based on a feature centrally located on the sheet. The map name also appears on the index sheets which are available from USGS or from local map distributors. Figure 7-1 shows the topo index used by the VGIS. It usually takes from two to four topo quad sheets to cover a town; each sheet costs $2.50.

Each topo sheet covers an area of approximately 8.6 x 6.25 miles. Topographic information (elevation) is printed on each map sheet in the form of contour lines. Boundaries are provided for towns, counties, national forests, military reservations, etc. Tics for three different coor-



USGS 7½ Minute Quadrangle Reference Map With USGS Index Codes

Figure 7-1.

dinate systems (explained in more detail in Chapter 9) are provided along the map margin:

- geographic coordinates (latitude/longitude) shown in 2.5 minute intervals with black tics labeled with black numbers,
- UTM coordinates shown at 1000 meter intervals by blue tics with black numbers, and
- State Plane coordinates shown at 10,000 foot intervals by black tics with black numbers.

These can be seen on the Mt. Philo quad which is included in the handbook pocket.

Photographs

The primary photographic source that Vermont communities will utilize is the *orthophotograph* or *orthophoto.* An orthophoto can be used as a planimetrically accurate map because the scale distortions that are inherent in aerial photographs have been removed.

Orthophotos, such as the one for Mt. Philo, are the standard base for local mapping in Vermont. They cover the entire state at a scale of 1:5000 (Figure 7-2). Some of the more developed areas are also mapped at a scale of 1:1250. Each Regional Planning Commission has an index showing which orthophotos are required to cover each municipality. A typical town index sheet and accompanying list are shown in Figure 7-3 and Table 7-1. Each orthophoto has a unique name and number. The number, which is printed in large type in the lower right corner of each sheet is derived from the coordinates of the southwest (lower left) corner of the sheet. The coordinates are given in thousands of meters with the easting first and then the northing. Thus the coordinates of the southwest corner of sheet 092196 (the Mt. Philo orthophoto) are 92,000 meters east and 196,000 meters north of the false origin for the Vermont State Plane Coordinate System.

Each 1:5000 scale orthophoto covers an area of 4,000 meters by 4,000 meters. The three coordinate systems printed on topo quads also appear on Vermont orthophotos:

- geographic coordinates indicated by white tics at 30 second intervals,
- UTM coordinates indicated by broken black tics at 500 meter intervals along the margin of the image, and
- State Plane grid superimposed over the photo image in white at 500 meter intervals.

An orthophoto, if recent, is an excellent source of information about land use and land cover in the community. Many features such as

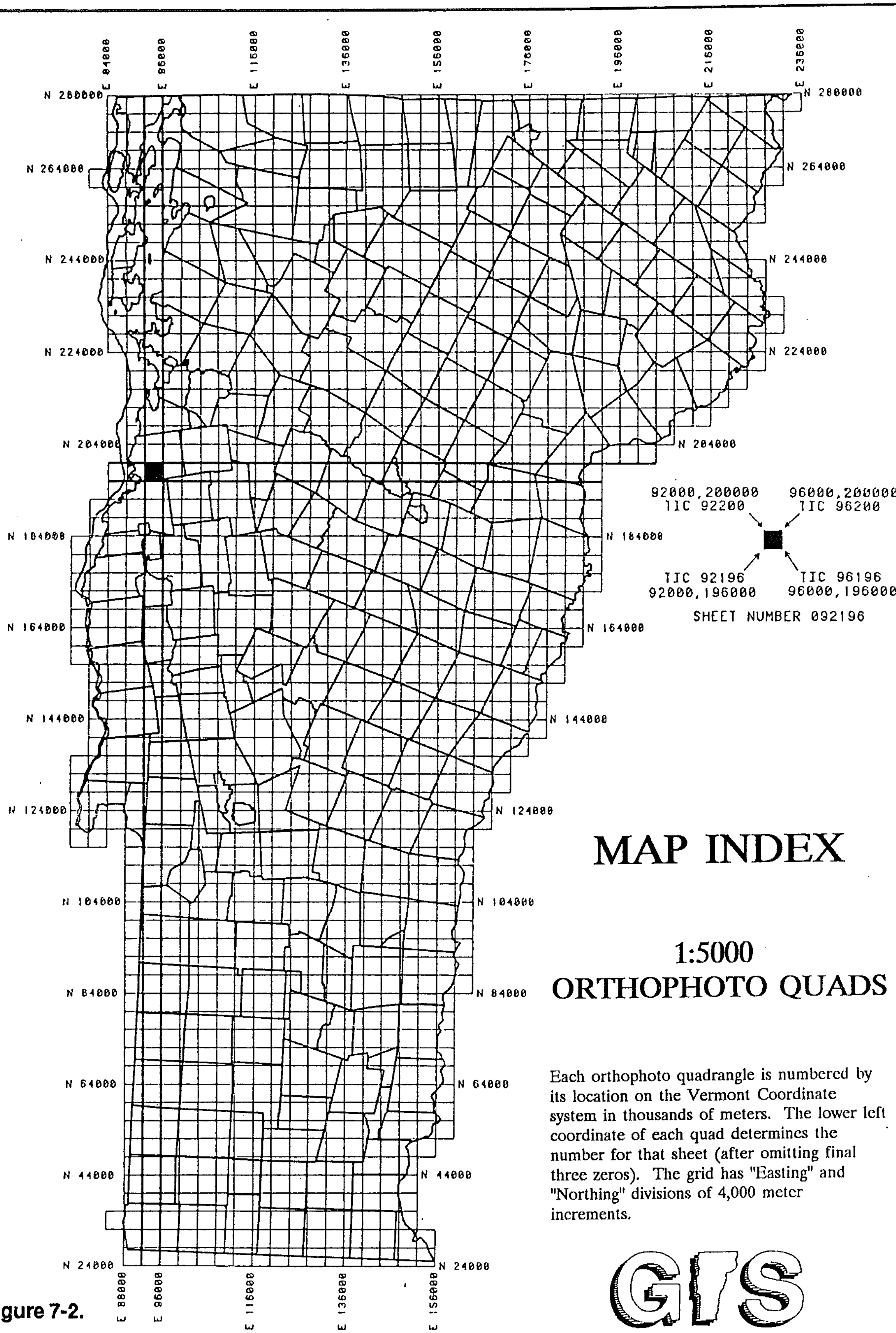
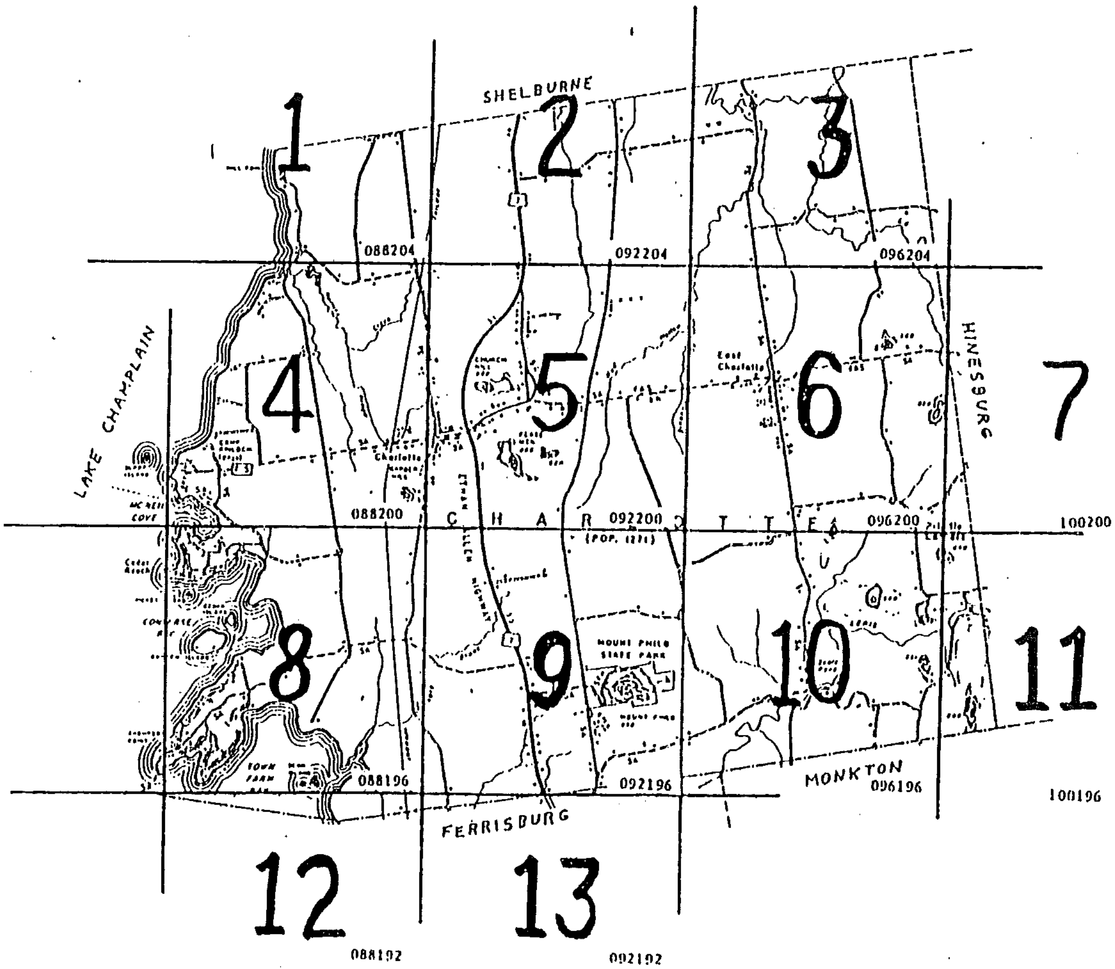

E 84000
E 96000
E 116000
E 136000
E 156000
E 176000
E 196000
E 216000
E 236000
N 280000
N 264000
N 244000
N 224000
N 204000
N 184000
N 164000
N 144000
N 124000
N 104000
N 84000
N 64000
N 44000
N 24000
E 88000
92000,200000
TIC 92200
96000,200000
TIC 96200
TIC 92196
92000,196000
TIC 96196
96000,196000
SHEET NUMBER 092196
MAP INDEX
1:5000
ORTHOPHOTO QUADS
Each orthophoto quadrangle is numbered by its location on the Vermont Coordinate system in thousands of meters. The lower left coordinate of each quad determines the number for that sheet (after omitting final three zeros). The grid has "Easting" and "Northing" divisions of 4,000 meter increments.

Figure 7-2.

INDEX MAP

CHARLOTTE

SHOWING APPROXIMATE LOCATION OF
VERMONT BASE MAP ORTHOPHOTO SHEETS
1:5000-SCALE SERIES



- KEY -
096200 STATEWIDE SHEET NUMBER

6 LOCAL SHEET NUMBER
FOR THIS TOWN

VERMONT MAPPING PROGRAM
PROPERTY VALUATION & REVIEW DIVISION
AGENCY OF ADMINISTRATION
Date: 3/3/80 By: PJK

Figure 7-3. The orthophoto index map for the Town of Charlotte as provided by the Agency of Administration's Vermont Mapping Program. Sheet 9 is orthophoto #092196, which is in the Handbook pocket.

State of Vermont
Agency of
Administration

Division of Property Valuation and Review
43 Randall Street
Waterbury, VT 05676

Vermont Mapping Program

To: Town and Village Officials

From: Program Manager

Date: March 1980

Subject: Vermont Base Map Sheet Listing and Layout

Sheet No.	Sheet Name	Statewide Sheet No.
1	HILL POINT	088204
2	SHELBURNE SOUTH	092204
3	CHARLOTTE-SHELBURNE	096204
4	CHARLOTTE VILLAGE WEST	088200
5	PEASE MOUNTAIN	092200
6	EAST CHARLOTTE	096200
7	HINESBURG	100200
8	THOMPSONS POINT	088196
9	MOUNT PHILO	092196
10	SCOTT POND	096196
11	HINESBURG SOUTHWEST	100196
12	HAWKINS BAY	088192
13	NORTH FERRISBURG	092192

Table 7-1.The list of orthophotos covering the Town of Charlotte as provided by the Agency of Administration's Vermont Mapping Program. Sheet 9, Mt. Philo, is the orthophoto in the Handbook pocket.

buildings, stone walls, and roads, are easily identified. The accuracy of the image on an original orthophoto (not on a paper print) is +/- 10 feet, meaning that 90 percent of the tested points on the photo meet this tolerance.

Paper print copies of orthophotos are available to municipalities at a cost of $10 from the Division of Property Valuation (see Appendix 5). A typical community requires 12-18 "orthos" for complete coverage.

Most Vermont communities will have been included on many other aerial photographs and satellite images. Unless these images have been rectified to remove distortion the information they provide will not be planimetrically correct and will be difficult, if not impossible, to accurately register to other map layers data in the computer database. Nevertheless, aerial photos and, to a lesser extent, satellite imagery can provide a wealth of background and reference information for a community inventory. Various agencies of the federal government have been flying airphoto missions since the late 1920s and these photos can provide a historical perspective on such topics as land use, forest cover, erosion, settlement, development, and lake levels. Private consultants and the RPCs can help unearth existing airphotos of a community. Appendix 5 lists agency sources for these photos, as well.

To facilitate base mapping and parcel mapping, a community or group of communities may contract with an aerial photography firm to fly a new set of controlled airphotos. In addition to providing the base for accurate parcel and town boundaries, the photos will be an excellent source of information on current land use, forest lands, buildings, surface water, and other themes.

Resolution of satellite imagery is too poor to be of use for most community inventory purposes but it may provide relevant information for regional studies or special projects, e.g., documenting forest dieback or gypsy moth defoliation. Since there are many satellites creating many different types of images, it is best to get help from the RPC, a consultant, or directly from USGS Eastern Mapping Center (see Appendix 5) when trying to locate suitable imagery.

Tabular Data

There is an almost endless supply of tabular data (tables and lists) that could be entered into a GIS provided it can be accurately tied to a location on the earth. The grand list, deed descriptions, public works installation and maintenance records, school district enrollments, and police and fire department records are some of the most obvious.

Digital Data

There is an increasing store of digital data available to Vermont communities. Of most interest will be the data layers created by the OGIS (parcel and town boundaries), UVM (soils and surface water), RPC's and contractors working on local and regional projects in the state, and various state agencies. Vermont state agency digital databases include:

- 1:100,000 scale USGS DLGs,
- hazardous waste sites,
- pollution source inventory,
- dam locations,
- natural heritage sites,
- mineral resources,
- water quality sample sites,
- 1:24,000 scale well-head protection areas, and
- CAPTAP.

Most of these data sets will be at a scale and in a format consistent with the standards established by the OGIS. A current listing of all pertinent digital federal and state data is available from the OGIS. In addition, some contractors have started providing parcel and subdivision surveys to towns in digital as well as paper form.

At the federal level there are several digital databases that GIS users will be interested in. These include *digital elevation models* (DEMs) and *digital terrain models* (DTMs) created by USGS, street networks and census tracts included in the Bureau of the Census' TIGER files for the 1990 census, and USGS *digital line graph* (DLG) data. Users should expect that any of the digital data sets not specifically created for use by Vermont communities will have to undergo some manipulation (scale and projection changes) and re-coding before they are compatible with the rest of the GIS database. RPCs can be helpful in accessing and evaluating these data sets. For more information please refer to Appendix 5 or contact the OGIS.

The rest of this chapter will concentrate on how to convert the non-digital data to digital format principally through the process of digitizing.

Spatial Data

Map Compilation

Usually some preparation of source maps is necessary before the conversion process can begin. This can range from simply organizing and assembling the maps to a detailed review and revision of the contents. The community GIS committee (discussed previously) is capable of carrying out this important step, but should do so only after consultation with the individuals who will do the digitizing. A great deal of effort is often required to locate missing information or to reconcile discrepancies among source documents. A community can save itself a considerable amount of money if it is willing to do this rather than pay a service center or contractor to assemble and prepare the source documents.

Map Registration

For maps to be usable as GIS data sources they must be registered to known real world or earth coordinates. Without identifiable tic marks, the information on the map cannot be spatially related to other information in the database. Before any further effort is expended on preparing a map for automation, four points with known coordinates must be identified on each map sheet to be digitized. As long as the user specifies which system it is, any coordinate system can be used since the GIS software can mathematically convert from one coordinate system to another.

Drafting

When the database design calls for separating the information found on one source map into several map layers, it may be more efficient to re-draft the information onto separate mylar overlays registered to orthophotos rather than to digitize directly from the source document. The orthophotos have the required four tic marks and, because they are corrected aerial photographs, it is easy to identify and correctly position features to be drafted.

Ideally *chronoflex* versions of the orthophotos should be used because they are stable-based (i.e., undergo minimal shrinking and swelling with changes in temperature and humidity). However, because chronoflex copies are very expensive ($85 each) most communities will use paper *diazo* copies ($10 each) made from the originals. The paper print orthophotos should be protected from fluctuations in temperature and humidity as much as possible, but it is inevitable that the paper will shrink and swell. A paper print orthophoto may swell by as much as 0.2", which may seem insignificant until we calculate that, at a scale of 1:5000, this represents a distance of 83' on the ground. This obviously affects measurements taken from the orthophotos and registration of data layers in the GIS database.

For the same reason, all overlays should be drafted on mylar, which is a dimensionally stable material, rather than on paper or acetate. If the overlay material is frosted mylar, ink or pencil can be used for drafting. If the overlay material is clear mylar, ink must be used. To maximize positional accuracy of the features being drafted, very fine lines should be used, whether ink or pencil. Technical drafting pens with water-insoluble ink are ideal.

The mylar sheet should be firmly affixed to the orthophoto using drafting tape. Before drawing any features, trace the four corner tics onto the mylar as precisely as possible and label them. Several themes or layers can be drafted onto one mylar overlay if they are drawn in different colors that are easily distinguishable during the digitizing process. When drafting polygons, make sure that they close exactly. Provide keys on the overlay and make notes for the digitizer operator to refer to, if necessary. Remember that the objective is to make things as easy for the digitizer operator as possible.

As an example, assume that the Champlain GIS Committee has gathered information on forest type, historic sites, and surface water. They cut mylar sheets and tape them to each of the orthophotos using drafting tape. Then they carefully trace the four corner tics on each sheet and label them with their tic IDs. They label each overlay with the ID number of its orthophoto. Each theme is traced with a different colored pencil: green for the forest information, red for the historic sites, and blue for the water features. As a new orthophoto is begun, lines are *edgematched* from sheets previously completed to ensure that all lines connect from sheet to sheet and that all polygons are closed. A code is given to each polygon or line segment (Figures 7-4 and 7-5).

Redrafting is a time consuming step but it will more than pay for itself in the end because digitizing will be much easier, faster, and more accurate. Editing out errors after the initial digitizing is very laborious and requires more experienced personnel than does drafting or digitizing. (It takes roughly three times as long to "fix" a line through the editing process as it does to enter that same line during the initial digitizing process.) With minimal training and supervision from the digitizer operator, this re-drafting is a step that a community GIS committee can perform very successfully.

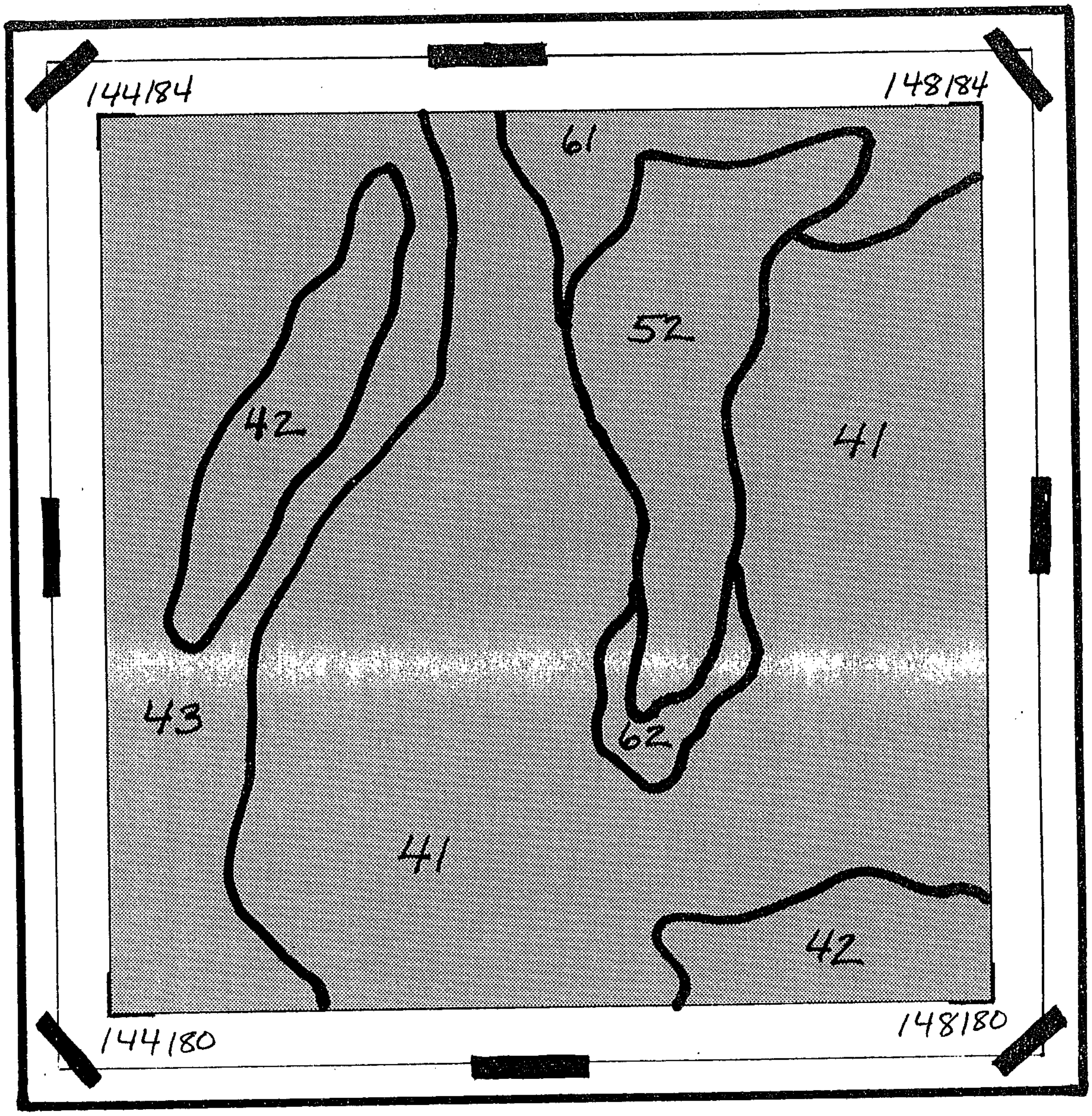


Figure 7-4. Land cover drafted and coded on a mylar overlay taped on to an orthophoto. Deciduous forest = 41, coniferous forest = 42, mixed forest = 43, lake = 52, forested wetland = 61, and non-forested wetland = 62.

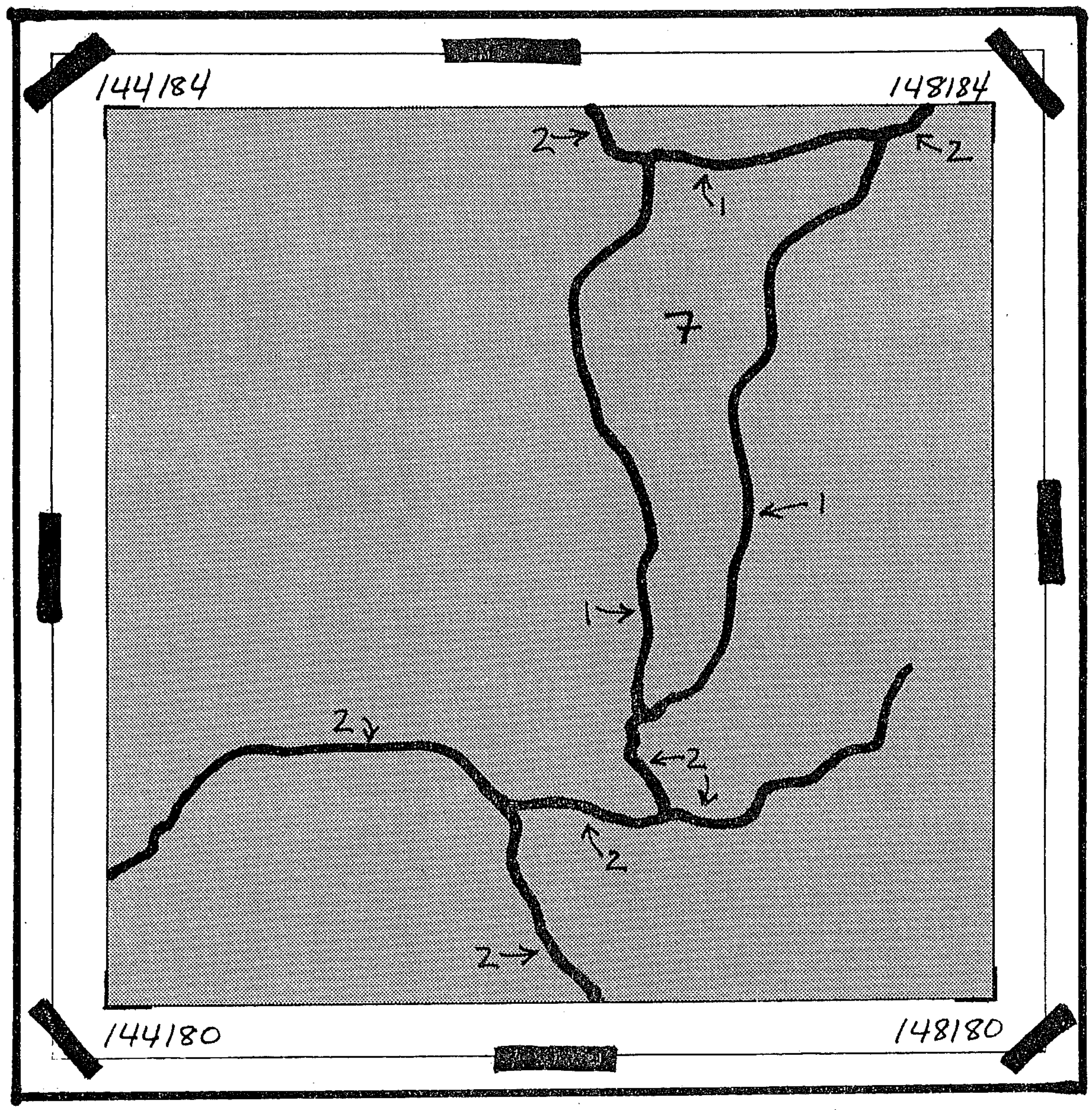


Figure 7-5. Surface water drafted and coded on a mylar overlay taped on to an orthophoto. Lines representing lake shorelines are coded as "1," and lines representing streams are coded as "2." The lake itself receives an ID number of "7" to link it with descriptive information to be typed into the computer database later.

Digitizing

Digitizing is the process of tracing the points, lines, and polygons found on a map with an electronic device that records the x,y coordinates of the features and enters them into the computer. A unique ID is entered for each feature along with simple attribute information (e.g., road class for a roads layer). More extensive tabular information is usually entered separately using a keyboard (see below). A good digitizing tablet is accurate to .002 inch, so effort expended on careful preliminary drafting pays off. The operator enters a code to identify the layer being digitized and then the coordinates of the four corner tics. Proper entry of these four corner tics will ensure the proper geographic location of the map features digitized.

An operator digitizing the layers described above would first affix the overlay to the digitizing tablet with drafting tape. He/she would then enter the code for the roads layer using buttons on the digitizing cursor. Then, carefully positioning the cross-hairs of the cursor over each corner tic, in turn, its position and ID is entered into the computer (Figure 7-6). Before proceeding further, a measurement of the positional accuracy of the four corner tics is automatically calculated by the computer. If the error exceeds a certain standard then the operator does not proceed with digitizing. This is to ensure that only accurately registered information is entered into the GIS.

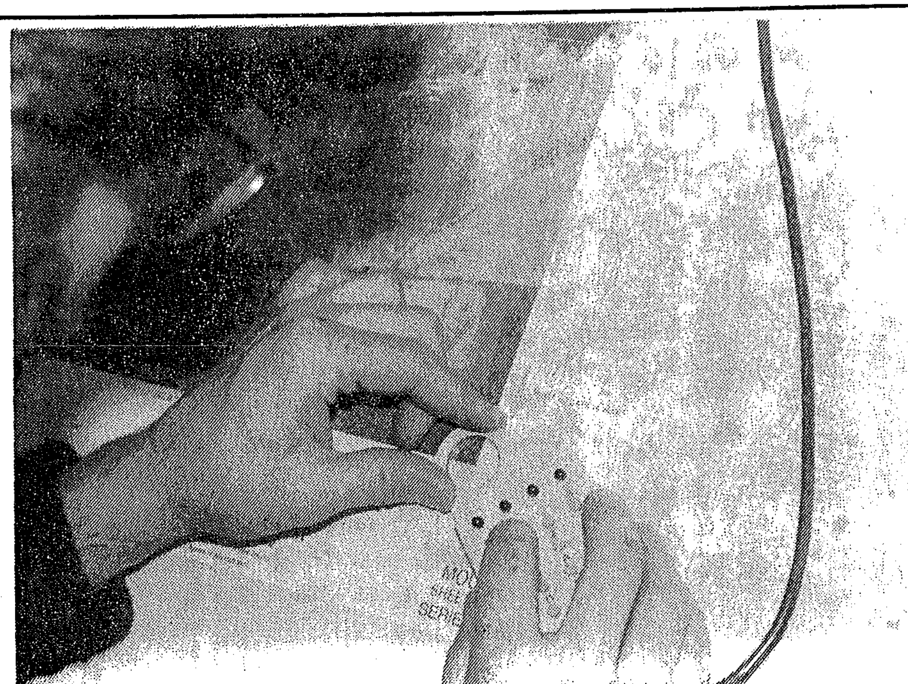


Figure 7-6. Entering the coordinates of an orthophoto corner tic into the computer.

Once the overlay is precisely registered, the operator uses the cursor to trace the lines and points for each layer. The computer automatically assigns a unique ID to each point or arc (line segment) as it is entered. The attribute information (e.g., forest stand class) can be entered during the initial digitizing using the cursor buttons or entered later using the keyboard. Using the computer screen, the operator can keep track of digitizing progress.

When all the map features from one overlay have been digitized, the operator checks the work using the GIS *edit function.* When the digitized file looks clean, the operator has the computer plot a map at the same scale as the source overlay. The two are compared and any discrepancies in the plotted version are marked for further editing. Similarly, the digitized lines from adjacent sheets are compared to ensure that the lines connect up properly from sheet to sheet. When the edit plot matches the source map the digitized data are saved as part of the permanent database.

For each data layer, and each orthophoto, the operator keeps logs which include such items as the operator's name, the accuracy of registration, any codes used, the source of the digitized information, the date and accuracy of the source, the date of digitizing, and any problems or comments that are relevant. This becomes part of the documentation for the layer. Examples of this data layer documentation are provided in the next chapter.

Digitizing is labor and machine intensive. The road network for one orthophoto of an average Vermont town would require 20-25 hours to digitize and edit. While expensive, digitizing is still the most common means of entering spatial information into a GIS.

Scanning

Scanning is a newer and faster method of converting spatial information into a digital form. An electro-optical device automatically captures all text and symbols on a map and converts them into a raster format. The raster format is then converted into vectors (lines) for input into a GIS. While scanners are fast and accurate when compared to manual digitizing, a great deal of post-scanning work must be done by an operator to identify text and to identify and label features types (points, lines, polygons). The scanner cannot tell one line from another (See Appendix 3).

COGO

While still fairly rare, an increasing amount of information will become available to communities in the form of *coordinate geometry* (COGO). Distances and bearings surveyed from known starting points will be provided in a file that can be entered into the computer. This is most commonly done by surveyors for property boundaries. Some GIS packages, including ARC/INFO, have the ability to convert this COGO information into the vector format needed to represent points, lines, and polygons. This method of spatial data entry bypasses the hardcopy map phase altogether and has the potential to be extremely accurate.

GPS

Global positioning systems (GPS) is a new technology that relies on satellites to determine the precise geographic coordinates of a feature on the ground. For example, communities could use GPS to locate wells, wilderness trails, or wetland boundaries. High relative accuracies can be obtained much more cheaply than by conventional surveying techniques and some day this method of determining ground location may replace surveying. At present the technique is limited by the small number of GPS satellites in orbit.

Attribute Data

Every spatial feature entered into the GIS will have at least one item of attribute or descriptive data associated with it and that is its unique ID. This ID is automatically assigned by the computer when the spatial feature is entered (usually by digitizing). An unlimited amount of attribute or descriptive data can be entered into the database for each spatial feature. As was described in Chapter 3, the descriptive information is linked to a spatial feature via the unique ID.

Rather than using lengthy descriptions, attribute information is stored in a coded digital format. So, for example, using the VGIS land use coding scheme, retail commercial use is coded 121, mobile home parks are coded 114, and mining operations are coded 137. Standards for attribute coding are being developed both within Vermont and throughout the U.S. Before a community devises its own scheme it should consult with the RPC and the OGIS to see whether existing schemes can be used or modified for the community's purposes. This avoids "re-inventing the wheel" and ensures that the town's database can be used as part of regional, state, and national databases.

Even natural and scenic features such as waterfalls can be described in digital format for inclusion in a GIS database. Figure 7-7 is the data definition file developed by the Agency of Natural Resources for waterfalls, cascades, and gorges. For each attribute there is an item name, a description of that item, the type of data storage, the width allowed for storage of the data, and the number of decimal places. The codes used are defined at the bottom. Thus we can see that the attribute describing the presence / absence of rare plants at a waterfall site is stored as an item called "RAREPLANT" that requires either a "yes" or "no." This is a character data type with a width of one since only a "Y" or "N" will be typed in. For the character data type there are no decimal places. If we look at the explanation of the codes, we can see that the example provided, Lana Falls, is described as being private, messy, and offering great swimming.

Sample Attribute Definitions for Waterfalls, Cascades and Gorges

May 9, 1990

Data Layer: Waterfalls, Cascades and Gorges from ANR publication (see Data Source)
Coverage Name: WATCASGO
Feature Type: Point locations
Data Source: All attribute information is contained in "Waterfalls, Cascades and Gorges of Vermont", 1988, VT Agency of Natural Resources (unless otherwise noted).

Attribute	Item Name	Description	Type	Width	Decimal Places	Example
Identifier	ID	basin#report# (basin = 1 to 17)	I	5	0	17999
Type	TYPE	W, C or G (upper case)	C	1		W
Name	NAME	Site name (upper/lower)	C	25		Lana Falls
Length (ft)	LENGTH	Horizontal	I	4	0	9999
Width (ft)	WIDTH	Horizontal	I	3	0	999
Total drop (ft)	DROP	Vertical	I	3	0	999
Slope (degrees)	SLOPE	Avg, degrees	I	2	0	99
Wall height (ft)	WALLHT	Vertical	I	3	0	999
Rare plants	RAREPLANT	Y or N	C	1		Y
Flow regulated	FLOWREG	Y or N	C	1		N
Privacy	PRIVACY	see Codes	I	1	0	5
Tidiness	TIDY	see Codes	I	1	0	3
Swimmability	SWIM	see Codes	I	1	0	4

Codes

PRIVACY:
1 = not secluded or wild
2 = somewhat secluded
3 = wild
4 = very secluded
5 = private

TIDY:
1 = clean
2 = fairly clean
3 = a mess

SWIM:
1 = good bathing
2 = fair swimming
3 = good swimming
4 = great swimming

Figure 7-7. The data definition file developed by the Vermont Agency of Natural Resources for waterfalls, cascades, and gorges.

Typing attribute data into a GIS can be facilitated by customized data entry menus that prompt the operator for the next piece of information to be entered. Quality control can be facilitated through the use of simple programs that check to see that data values are within a valid range and that there are no blanks. Still the attribute data must be thoroughly checked and edited before it can be entered into the permanent database.

Updating

Keeping a GIS database current is far less time consuming than keeping paper maps current. For example, if a parcel is subdivided and new roads constructed, the road changes are made to the affected layer(s) of the database and a new map can be quickly plotted. First the new property boundaries are registered to the orthophoto base and then digitized into the computer. Because the database is topological, it is an easy matter for the computer to re-form any affected polygons (neighboring parcels) and reassign attributes, if needed (Figure 7-8). Then any attributes associated with the new parcel are simply typed into the tabular database. This means that once a community has an accurate parcel map entered into the GIS, yearly (or more frequent) updates are quickly and inexpensively done compared to the time required to redraft a planimetric map.

Most data layers have value as historical records so old versions of data layers should not be discarded. Time-series studies of land use change, settlements, forest cover, wildlife habitat, lake levels, etc. can be very enlightening. It is important to retain the documentation with the outdated data layers as well, so there is no confusion in interpreting historical data.

Once the spatial and attribute data are accurately entered into the GIS, there are virtually no limits to applications. Keep in mind, however, that each data source has an accuracy level associated with it, and any analysis or combination of layers will be only as accurate as the least accurate level incorporated. If GIS products are to be used with confidence and credibility, it is important not to oversell the level of accuracy.

Summary

- To be usable in a GIS, information sources in diverse formats must be converted to a common digital format.
- Most spatial data will be entered into the GIS by digitizing map features that have been redrafted onto orthophotos.

Figure 7-8. Parcel information stored in a GIS before and after a parcel is subdivided. Acreages are automatically computed by the GIS.

- Registration of source maps to known earth coordinates is critical if data layers are to overlay properly in the GIS database.
- Updating digital data in a GIS database is easier than updating hard copy maps.

References

Anderson, J.R., E.E. Hardy, and J.T. Roach. 1972. A Land-use classification system for use with remote-sensor data. USGS Survey Circular 671. Washington, DC.

GIMS (Geographic Information Management System) Committee. 1989. Multi-purpose geographic database guidelines for local governments. Photogrammetric Engineering and Remote Sensing 55(9): 1357-1363.

Vermont Office of Geographic Information Services. 1990. *DRAFT Guidelines for Developing Attribute Definitions and Codes for Use with GIS.*

Chapter 8 Management and Policy Issues

Geographic information management is likely to become a service managed by local government just like sewer, water, and power utilities. In the last decade, greater sophistication of the technology and wider options for its use have brought GIS within the grasp of local governments for the first time. However, the promise of GIS comes laden with complex institutional issues including data management, system access, and legal issues. All GIS users need to be aware of these issues. The community that decides to develop its own GIS facility will have to grapple with each issue and develop policies that are consistent with legal precedents and the spirit of public service.

Data Management

The database is the most important part of a GIS effort. It is an organizational asset that increases in value over time and as a coherent program of management procedures is initiated. A community's investment in equipment and personnel will be wasted unless carefully thought-out policy and procedures are in place to ensure the appropriateness, accuracy, currentness, and security of the data. To ensure the viability and value of the database, the community GIS Committee should consider data standards, documentation, quality control, updating, and security.

Data standards are very important in ensuring that each new data layer created for a community is compatible with existing data layers. Data standards also ensure that data are collected and stored in a format that is suitable for a wide variety of applications and users, and that they can be combined with adjoining town, regional, and statewide GIS data for regional analyses.

Because development of data standards requires a great deal of detailed technical input from a variety of disciplines, it is not a task that communities or RPCs are expected to perform. The OGIS, through consultation with municipalities, the RPCs, state and federal agencies, and private consultants, is developing GIS data standards applicable for Vermont. So far, the OGIS has published "Digitizing Data Standards" and "Coordinate System Standards." These standards should be followed when developing data layers. When a community contracts for GIS services, it should specify adherence to VGIS standards.

The Vermont "Digitizing Data Standards" address the issues of

- source map media,
- geographic registration of maps,
- digital tolerances,
- data capture methods,
- coincidence features,
- attribute coding schema,
- cartographic accuracy,
- spatial topology,
- edge matching,
- documentation,
- delivery of digital data, and
- accuracy assessments.

The Vermont Coordinate System Standards address

- map projections,
- coordinate systems, and
- digital data conversion procedures.

These standards are the first two of a complete set of data standards being developed within the State. Available in draft form from the OGIS are the following:

- *Guidelines for Developing Attribute Definitions and Codes for Use with GIS*, and
- *Digital Format for pcARC/INFO GIS Data Distribution.*

Eventually, all data standards developed by OGIS will combined in one volume to be titled *VGIS: Policies, Standards, Guidelines, and Procedures Handbook* (Figure 4-1).

Data documentation will provide future users of GIS data with the information they need in order to assess the utility of the data for a particular application, determine compatibility with other GIS system digital data, and to produce additional data layers compatible with existing data. All map layers should have an accompanying documentation file following the structure and content recommended by the OGIS (Figure 8-1).

In addition to the documentation file, a data layer history file should be set up to record changes to the data layer over time. Figure 8-2 is

```
COVER-NAME      = CH
COVER-CONTENT   = DEER WINTERING AREAS - POLYS
SOURCE-AGENCY   = VT FW
DATA-SOURCE     =
SOURCE-MAPS&DATE  .  = USGS 7.5 MIN TOPO 1983 PLAINFIELD
SOURCE-SCALE    = 1:24000
SOURCE-MEDIA    = PAPER
SOURCE-ACCURACY     = 500'
SOURCE-RESOL    =
COMPILATION-DATE    = 1989
DIGITIZING-DATE     = 11/28/89
DIG-PERSON      = DAVID SAUSVILLE
DIG-DEVICE      = GTCO 5A Digi-Pad
DIG-RESOLUTION = .001 inch
METHOD-QUAL-ASSR    = OVERLAY MAP, REVIEW BY BIOLOGIST
MAP-PURPOSE     = WILDLIFE & PUBLIC PLANNING
PROJECTN-&-UNITS    = STATE PLANE & METERS
DATUM     = NAD 1927
DATA-TYPE = POLY
GIS-SOFTWARE    = pcARC/INFO
SOFTWARE-VERSION    = 3.3
RMS-TOL   = 1.2
DANGLE-LENGTH   = 48
LINE-ACCURACY   = 90% W/IN .01 IN
MAP-EDITION     = DRAFT
DIG-ORGANIZATION    = VT ANR/GIS
CONTACT-PERSONS     = John Dudley, Chief of ANR/GIS
STREET-ADDRESS = 103 S. Main St., Center Bldg.
CITY-STATE-ZIP = Waterbury, VT 05667
PHONE     = (802) 244-7340
NOTES1    =
NOTES2    =
```

Figure 8-1. Example of a data layer documentation file for a deeryard layer developed by ANR (courtesy of the OGIS).

```
DATAFILE NAME  = CHZON.HST
DATE = 05/25/90
OPERATOR  = BILL HEGGY
MAP  = VT ORTHO 092200
PROCESS   = ARCEDIT
RMS  = .002
NOTES     = UPDATED INDUSTRIAL DISTRICT BASED ON ENGINEERS SURVEY
```

Figure 8-2. File Structure for Data Layer History. This history file for the Champlain zoning layer shows that on May 25, 1990, Bill Heggy updated an industrial district using the ARC/INFO module ARCEDIT and had a registration root mean square error of RMS = .002. The industrial district was located on Vermont orthophoto #092200

an example of such a file that follows the OGIS recommendations. A history file will provide valuable information about the most recent version of a coverage as well as the important changes that have occurred.

Quality control is an important management concern when building a GIS digital database. Procedures must be implemented to ensure that GIS data meet the established data standards discussed above. The quality control process should include data checks as data are entered to confirm proper feature placement, and internal checks to confirm attribute codes and formats. Setting up a quality control system requires considerable time initially but will improve overall project efficiency and data quality. In order to facilitate quality control procedures, progress charts and/or quality control sheets should be used throughout the GIS database building process. Figure 8-3 is an example of a quality control log that might be used to monitor progress during digitizing and initial data entry.

Figure 8-3. A data entry quality control sheet indicating that a task was completed, checked, the date, and the operator.

TASK	DONE	OK	DATE	INT.
Arcs Digitized	X	X	05/22/90	BH
Label points added	X	X	05/24/90	BH
Arc attributes attached	X	X	05/25/90	LB
Label attributes attached	X	X	05/25/90	DC
Unique arc -ID's created	X	X	05/26/90	BH
Unique label -ID's created	X	X	05/26/90	BH
Annotations added	X			

Similar check sheets should be used for pre-digitizing setup, digitizing and map layer creation, error-checking procedures, and map production. In addition to these sheets, a log should be kept for documentation of errors encountered during all phases of map layer production. This log should include a narrative of the problem encountered, date, approximate coordinate location, and the steps taken to resolve the problem. This ensures that all problems are resolved before a data layer is entered into the permanent database.

Updating the database is critical to the long-term usefulness of the GIS as a planning and management tool. Communities will find that updating on a regular basis will also lower the long-term GIS management costs. The community GIS committee, discussed in Chapters 5 and 6, will play an important role in providing continuity in the town's GIS efforts. The committee should keep records of GIS activities, set up a system for addition of attribute information by the community, and schedule updates on a regular basis. Old GIS data layers should be archived for historical analyses.

Updating can involve changing spatial data (such as boundaries of a newly subdivided parcel), attribute data (such as a change in ownership for a parcel), or both. Making changes to the spatial data usually requires access to a GIS but the attribute information associated with the spatial features can usually be updated right in the town clerk's office. The community GIS committee should set up systems for updating attribute information that will encourage public works personnel, clerks, zoning administrators, and planning commission members to enter updated attribute information for certain map layers. A series of user-friendly programs can usually be written for commonly-used database management programs such as dBASE that will allow easy input of new information even by the novice computer user. Once the attribute data is updated, it can be easily related and transferred to the GIS system where the spatial features are stored. As an example, the zoning administrator could enter information on building permits issued during the month into the computer database at the town clerk's office. This information could then be associated with the GIS parcel map for the town. Periodically, a map could be produced for the planning commission and the zoning administrator showing the locations of new buildings in town and the date the building permit was issued. This map could be used as a valuable indicator of growth areas and areas potentially requiring increased municipal services.

Data security is a very important aspect of overall data management and should be rigorously maintained. Regular system backups provide the best means of protection from data loss due to software or hardware system failure, or to the operator simply making a mistake. Backing up the system is done by copying data files from the computer hard drive to another storage medium. Backups should be regularly scheduled and given a high priority so that they are faithfully performed. (There are many sad tales of lost data that begin "If only I had ..."). Weekly backups should include all data that has been changed since the last backup. A cataloging system should be developed to allow quick access to the backup data in the event of a loss of original data. One catalog system involves using dates and a hardcopy print out to identify backups (Figure 8-4). These hardcopy print outs should be maintained in a chronological file.

Data backups can be stored on a variety of media including disks, tape cassettes, and high-volume data cartridges. The kind of media chosen will depend on the volume of data generated, the ease with which it must be retrieved, hardware cost constraints, and compatibility with other computer systems.

Figure 8-4. A printout resulting from backing up the F drive on September 4, 1990 onto Tape B. The backed-up file names and their file types are listed.

DATA BACKUP: F:090490 BACKUP TAPE: B

CONTENTS

\CHARLOTTE\SWPOLYCL	\CHARLOTTE\SOCL	\CHARLOTTE\LUCL
\DUXBURY\ZONECL	\DUXBURY\SWPOLYCL	\DUXBURY\TBCL
\DUXBURY\SWPOLYCL.KEY	\DUXBURY\ZONECL.KEY	\DUXBURY\INFO
\CHARLOTTE\INFO		

If a GIS project involves many months worth of work, then a copy of the backup data should be stored in a secure, fireproof area. Long-term archived data, whether on diskette, tape, or cartridge, should also be stored in the same way. Although access will be limited, the potential benefits of secure data will outweigh the inconvenience.

In addition to data loss through system failure, there is the potential for data loss through system tampering or inexperienced user access. All mainframe and mini-computers and most personal computers provide a mechanism for limiting access to programs, workspaces, and individual files. The most common mechanism is requiring that a password be typed in before access to a workspace is permitted. In a small GIS installation, each user would select a password to protect his/her own workspace. In a larger computing environment, the system manager may establish a hierarchy of access (see below) and passwords to protect all users and the system from unauthorized use and tampering.

Access to the System

If a community opts to develop its own GIS facilities it is presumably because it has a great number of potential users and applications. Regardless of the computer configuration selected, user access priorities, security measures, and accounting procedures will have to be established. To do so it will be helpful to categorize users (other than the designated GIS operator) according to the kind of functional access they will need:

1. The bulk of the demand on the system will be from users needing standard hardcopy products but not interested in analyses or interactive GIS access. No system access is required by the user so security is not a problem. Typically, requests would come from private citizens, realtors, foresters, and businesses.
2. Many users will want standard and custom maps and reports of the existing database but only infrequent analyses. Because their nonstandard GIS needs are infrequent, these users will probably

not have access to or be trained to use the system; consequently security will not be an issue. Users that would typically fall into this category would be the planning commission, the zoning commission, natural resources or conservation commission, and ad hoc citizen's groups.

3. Some users will need to enter tabular or graphic data and perform analyses periodically but not on a daily basis. These individuals would need some training (e.g., digitizing) and would pose the largest security risk since they would understand some system functions but not others. Security (data integrity) would be of particular concern if these individuals have access to the system via a network. Public works department staff members would be an example of this type of user. They may want to update infrastructure data layers on a quarterly basis, and also create custom analyses of particular areas (e.g., for maintenance or installation) on a sporadic basis.
4. A few users will want daily access to the GIS for interactive browse capabilities. These users are likely to include the municipal planner, manager, and the clerk. To ensure that data integrity is not jeopardized, foolproof, user-friendly interfaces will have to be developed, and the users will need training to become comfortable using them.

Legal Issues Surrounding Public Access

There are several legal issues surrounding public access to government-supported GIS facilities that communities should be aware of when considering developing such a facility. These are liability, copyright protection of the database and GIS products, the demands for public information placed on the system, and uniform pricing. An excellent discussion of these issues is presented in a report submitted to the Vermont Office of Geographic Information Services by PlanGraphics, Inc., entitled "Providing Access to the Vermont Geographic Information System: Legal Framework, Functional Access, and Cost-Price Model for Sale of Products and Services." The reader is encouraged to consult this document. A very brief synopsis is provided here so that communities are aware of the potential legal ramifications involved with developing a GIS facility wholly or partially supported by public funds.

Liability and Disclaimers for GIS Products

GIS agencies are potentially liable because the general public may put undue reliance upon maps and other products generated by the GIS. Appropriate disclaimer language should be included on all GIS outputs to help avert potential products liability claims from being filed and to provide a good defense against such claims should they be filed. Disclaimers do not automatically prevent liability. The objective of the map disclaimer is to alert users that errors are possible and that they need to consider the degree of reliance that is appropriate for their purposes. The disclaimer should indicate when the map was compiled, the source material, and should direct the user to that material for further information. The location, style, and size of the disclaimer relative to other map elements should make the disclaimer noticeable to the user.

If there is a contractual relationship between the GIS facility and other parties, the extent of the agency's liability should be defined in the contract. Proper disclaimers should also be included in subscription and database update agreements and should specify that services and not "goods" are being provided.

Use of Copyright for GIS Products

Copyright protection will be needed for GIS products and services if GIS facilities are to obtain control over cost recovery. The most important use of copyright would be protection of the "raw" database from unauthorized copy and resale. It is not clear how copyright protection can be extended to databases that are routinely updated. Technically, each update is a "changed work" and the copyright for the previous version would not apply. Perhaps the best means of applying copyright protection to a dynamic database is to include restrictions in contracts with users. In addition, maps should have the copyright symbol placed on them before distribution.

Vermont Public Records Law

The state policy regarding public records is that the free and open examination of records shall be allowed so long as the examination does not violate the right to privacy. The law is liberally construed to encourage free and open access to records (papers, reports, schedules, written and recorded matters produced or acquired in the course of agency business). Computer "records" are clearly records for purposes of Vermont law. State law limits cost recovery for copies of records so that unreasonable charges won't be used to frustrate access. The law also limits the response time to requests for access to the records for the same reason.

It is clear that the combination of the commercial utility of GIS and the procedures established by public records laws results in the potential for major operational problems for a governmental GIS facility. Unless a GIS facility can make a clear distinction between records and new information generated by the GIS (i.e., products and services made possible by the ability to perform spatial searches and overlays), they will face the prospect of having to make all their work freely available to all comers. A policy that distinguishes products and services from records will enable a GIS manager to maintain some control over staff time assignments and office management and to recover funds. Because there is no clear legal precedent for local government to market and sell products and services, GIS facilities will need to demonstrate that the public is better served if they have the authority to market and sell products and services.

Pricing of GIS Products

GIS managers, whether they operate systems for individual communities or RPCs, must develop prices for different products and services and also make clear the basis for any discrimination between types of GIS customers, the types of access to be allowed, and any price variations for the same product. A consistent, reasonable fee schedule will be important in gaining acceptance for the marketing of GIS products and services. Guidance on pricing policy will be available from OGIS.

Summary

- In the foreseeable future, GIS will become a utility managed, at least partially, by local government.
- GIS users need to be aware of issues pertaining to data management and security, system access, and legal issues.
- GIS standards and procedures to facilitate data management are being formulated and disseminated by the OGIS.
- Regardless of the type of user access to a GIS facility, procedures and policies will need to be established regarding user priorities, system security, and accounting.
- Salient legal issues pertaining to GIS facilities supported by public funds include cost recovery, access to public information, uniform pricing, copyright, and liability.

References

Archer, H. and P.L. Croswell. 1989. Public access to geographic information systems: an emerging legal issue. Photogrammetric Engineering and Remote Sensing 55(11): 1575-1581.

Vermont OGIS, 1989. *Providing Access to the Vermont Geographic Information System: Legal Framework, Functional Access, and Cost-Price Model for Sale of Products and Services.*

Vermont OGIS, 1989. *Digitizing Data Standards.*

Vermont OGIS, 1989. *Coordinate System Standards.*

Vermont OGIS, 1990. *DRAFT Guidelines for Developing Attribute Definitions and Codes for Use with GIS.*

Vermont OGIS, 1990. *DRAFT Digital Format for pcARC/INFO GIS Data Distribution.*

Chapter 9 Review of Cartographic Principles

Familiarity with basic cartographic principles is essential to those applying GIS techniques to local planning and resource inventories. Maps will be the source of much of the information that goes into a GIS database and they will also be the format most often selected for the display of GIS-generated inventories and analyses. Therefore it is important to understand how the purpose of a map determines its form and how map concepts and the elements of map design are employed to convey spatial information.

Types of Maps

Maps come in many forms and are asked to play a variety of roles:

- Maps are respositories of information in geographical format. This is the most basic use—the "what is where" use familiar to us in the inventory process of roads, soils, or forest stands, etc.
- Maps can serve as computational aids. For example, we can count houses or measure areas and distances.
- Maps frequently serve as an aid in navigation. They can show us how to get from point A to point B and often give us an idea of what's along the way. A state highway map (Figure 9-1) is probably the map most familiar to most of us.
- Maps can be a means of summarizing complex and voluminous data. Usually this is done by aggregating information and simplifying it for visual display, as in a map showing election results for the entire United States. At the town level, we might summarize in map form the number of building permits issued over a five year period to highlight areas of growth.
- Maps can aid in exploring data, and analyzing or forecasting from that data. The most familiar example would be the weather maps presented on television and in the newspaper (Figure 9-2). Similarly a composite map of a community's natural and cultural resources would help citizens analyze their options for the future.
- Maps can help visualize a situation that it is either hidden from our view or involves abstract data. For example a Federal Emergency Management Agency (FEMA) map such as the one shown in Figure 9-3 can help a town visualize what areas and

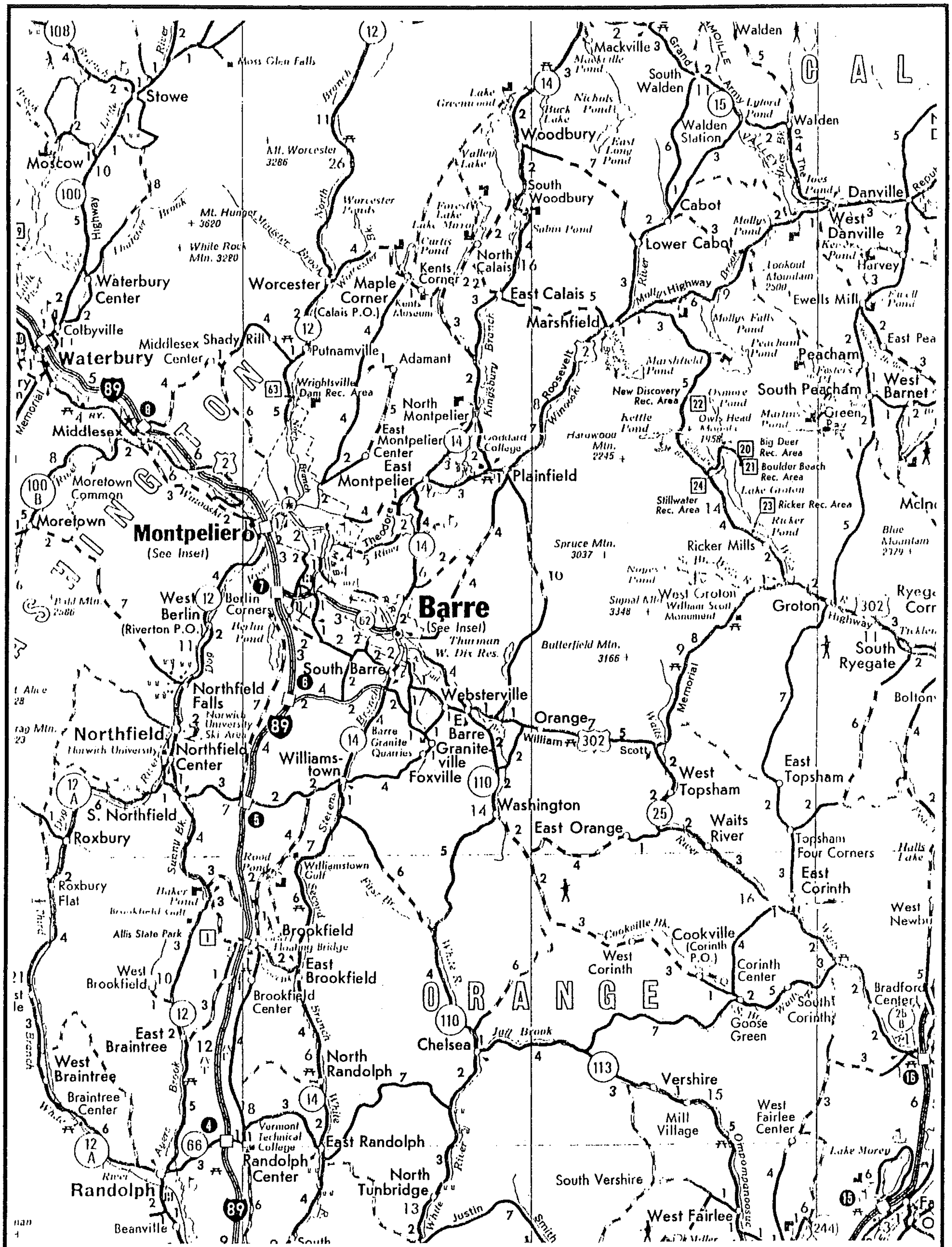


Figure 9-1. Section of 1980-81 Official State Map.

Figure 9-2. Weather maps help us understand weather phenomena and predict the future.

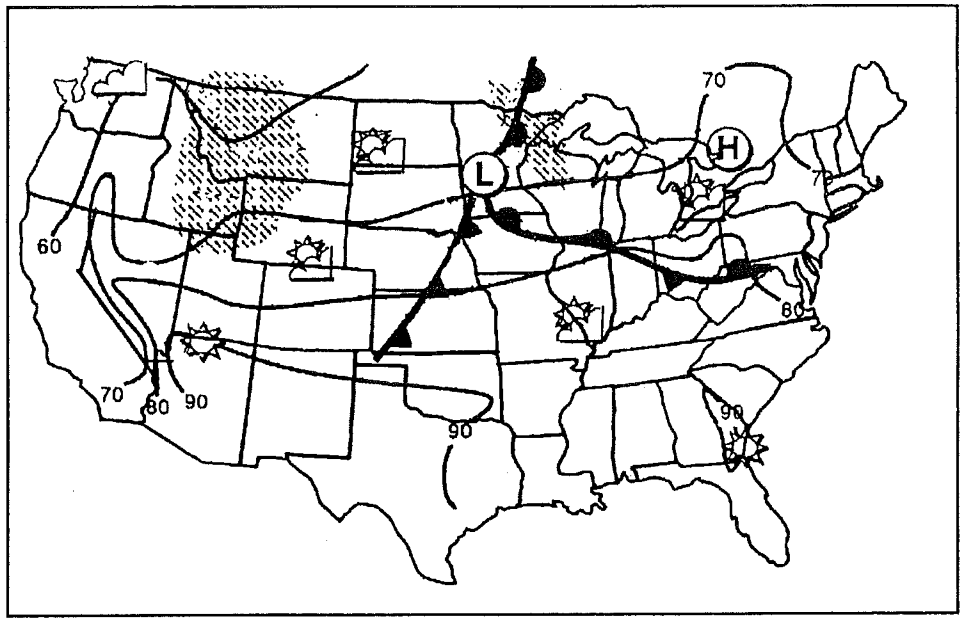
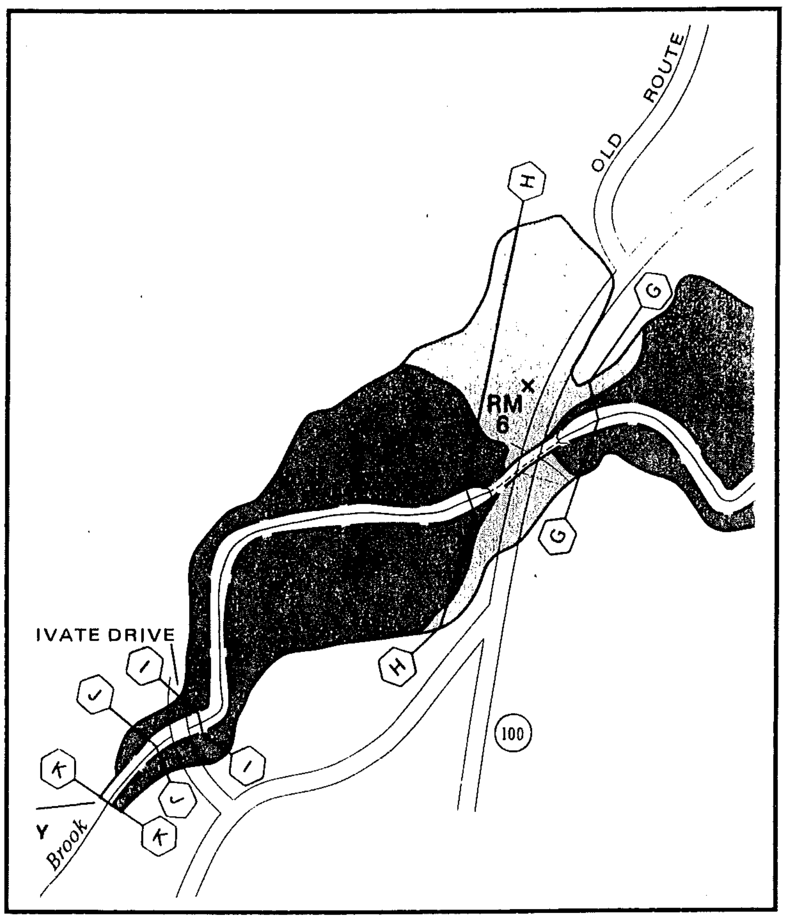


Figure 9-3. A section of the Flood Emergency Managemment Agency's *Flood Boundary and Floodway Map for the Town of Duxbury*, Vermont. Light gray represents the extent of a 500-year flood. Dark gray represents the extent of the 100-year flood.



structures are at risk of flood damage. This information can be incorporated into zoning and other regulations, if desired.

- And finally maps can serve as a trigger to stimulate thought, imagination, and discussion. A map showing the results of a full build-out analysis based on a community's current zoning is bound to spark a lively discussion at a public forum.

No one map serves all these functions, nor should it attempt to. There are three general categories of maps:

planimetric maps - These are maps that show only the horizontal position of features on the earth. This usually includes such features as ponds, rivers, mountain ranges, political boundaries, bridges, railroad lines etc. There is no attempt to represent any relief (vertical) information. A base map such as that shown in Figure 1-1 for the Town of Sutton, is an example of a planimetric map.

topographic maps - These are maps that present both the horizontal and vertical positions of features, as opposed to the planimetric map which shows no measurable relief. The U.S. Geological Survey's "topo quads" are probably the most familiar example.

thematic maps - These maps are designed to provide information on a single topic or a group of topics or "themes". The bulk of maps fall into this category. They can range from the simple to the complex and may or may not attempt to be geographically accurate. Examples of thematic maps include geologic maps, maps of average annual precipitation, location of flood hazard areas, and the distribution of farms by town (shown in a map produced for the Vermont Farmland Project, Fig. 9-4).

Map Concepts

Regardless of the purpose or form of a map, there are certain map concepts that are almost universally observed. These concepts include the principles of *classification, symbology, scale, resolution, accuracy, projections, and coordinate systems.* They should be considered when designing or using a map from which measurements must be made, or policy or legal decisions adduced.

Classification

Classification is the process of grouping items and putting a title or label on the group in order to aid thinking and communicating about the items. This artificial, and often arbitrary, organization is most clearly manifested in the limits we choose to form the classes. For example, although children in an elementary school have birthdays

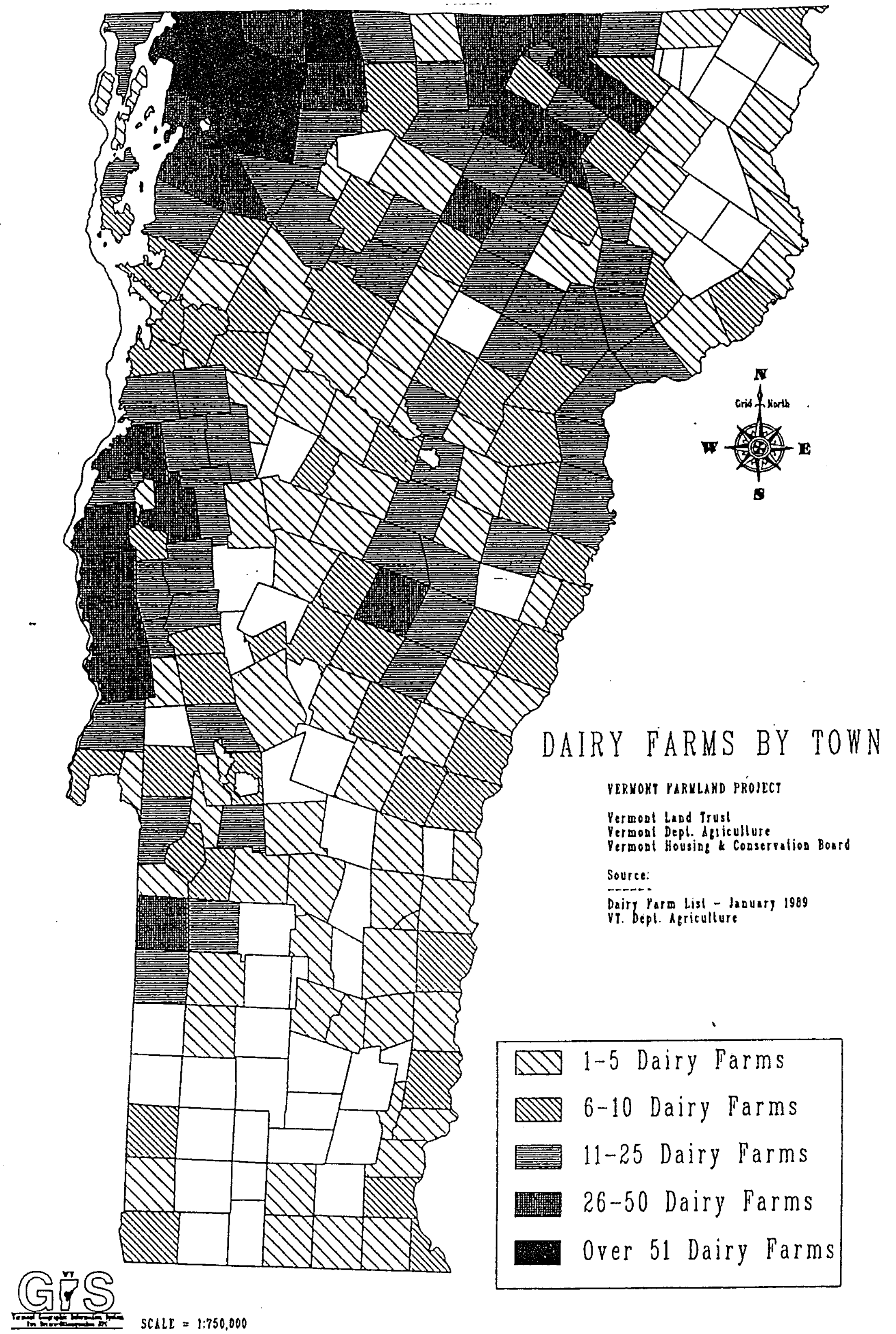


Figure 9-4. A thematic map summarizing the distribution of dairy farms by town (courtesy OGIS).

throughout the year, arbitrary birthday cut-off dates are established to assign the children to different grades. Although arbitrary, it is practical and efficient, and, most importantly, suits our purpose. Every classification scheme is chosen for a purpose"be it assigning school children to classes, allocating shelf space to products in a supermarket, or presenting types of land use on a map. The classification reflects the view of those gathering the information and the intended use more than the traits inherent in the items classified.

Information on variation is often lost in the process of classifying. The average or median test score of a class may be reported rather than the individual scores of 20 children. Therefore, the amount of variation within a class is an important consideration in setting class limits. We want the items within the class to be more like each other than like items in another class.

A related issue is the number of items to be classified and the number of possible classes. If there are only to be three teachers in our hypothetical elementary school, perhaps we should group the first and second graders together, the third and fourth graders together and the fifth and sixth graders together. But now we have too many items (children) per class and too much variation (in terms of academic ability), so we decide we need more classes (and therefore more teachers). These same considerations pertain to information to be classified and represented on a map.

Classification schemes need to be *exhaustive* and *mutually exclusive.* Each item should belong to one and only one class. If it's a good scheme, there should be no need for an other category. In our elementary school example, our classification criterion of birth date assures that there is only one appropriate class for each child.

So far, this discussion of classification has focused on what is called a *"discrete variable"*. That is, each item to be classified (in this example, children) is separate and distinct from the next. But many natural phenomena, and many that a community will want to depict on their maps, are what is called continuous. That is there are no distinct boundaries defining items but only smooth transitions. Examples of continuous variables include ambient temperature, slope, soil characteristics, and vegetation structure. Often, classification schemes for continuous variables rely on numerical class limits rather than the more qualitative definitions that must be applied to discrete variables. For example, if we want to classify slope, we have to decide what class limits are meaningful: 0 - 30, 31 to 60, 61 to 90 degrees? No, probably a more useful classification, at least for community planning purposes would have classes such as those used by SCS. Their classes are A: 0-3 percent, B: 3-8 percent, C: 8-15 percent, D: 15-25 percent, E: 25-60 percent, and F: over 60 percent. The variable (slope) remains the same, but our view of it is different because the classification scheme has changed.

Whether a variable is discrete or continuous and whether the classification scheme is based on qualitative or quantitative criteria, it is important that the class definitions be clear and well documented. If class definitions are well written, then many different individuals can use the classification scheme and come up with comparable results. This is essential for maintaining consistency because, in most mapping projects, many individuals will be involved in the mapping and updating process. The Vermont GIS Land Use Classification Scheme (Table 9-1) is one of many attribute coding schemes being developed by the OGIS as a state standard.

Map Symbols

All the information that appears on a map can be broken into two kinds of graphic entities"either *symbols or text.* The symbols are a means of indicating where an item exists or a phenomenon occurs in relationship to other items or phenomena. The text provides labels or other helpful information.

Symbols consist of three types"points, lines, and shading. These symbols can vary in their characteristics (size, shape, pattern, color, orientation, arrangement, and texture) to convey information to the map user. A well-known set of symbols are those appearing on the U.S. Geological Survey 7.5 minute topographic quadrangles, e.g., the Mt. Philo quad included in the handbook pocket. Some of the symbols used on the map are explained in the lower margin. A complete legend is available from USGS.

The cartographer takes advantage of the full range of possibilities in symbol types and characteristics to make a map that is both attractive and informative. He or she must also keep in mind how the map is to be reproduced. For example, if color reproduction is unaffordable, symbols and shading that will be distinguishable in black and white must be selected. Symbology and other elements of map design are selected in a context that is determined by two other groups of cartographic principles:

1. scale, resolution, and accuracy

2. projections and coordinate systems.

Table 9-1. The first three levels of the proposed VGIS Land Cover/Use Codes. Level IV provides even greater detail. For example, in Level IV, 125 Government is further subdivided to include: correctional, military, courthouse, postal service, administrative offices, emergency services, public works, and other government categories. Contact OGIS for the complete list of codes.

1 URBAN/BUILT-UP/DEVELOPED
11 residential
- 111 multi-family, medium to high rise apartments & condominiums with three or more stories
- 112 multi-family, low rise apartments and town houses, but not duplexes; less than 3 stories
- 113 single family/duplex
- 114 mobile home parks
- 115 group and transient quarters
- 119 other residential

12 commercial, services, and institutional
- 121 commercial retail
- 122 commercial wholesale
- 123 services
- 124 lodging
- 125 government
- 126 institutional
- 127 educational
- 128 indoor cultural/public assembly
- 129 other commercial

13 industrial
- 131 primary metal production
- 132 petrochemicals
- 133 primary wood processing/paper mills
- 134 stone, clay, glass
- 135 metal and non-metal fabrication
- 136 food processing
- 137 mining
- 138 home/cottage industries
- 139 other industrial

14 transportation, communications, & utilities
- 141 air transportation
- 142 rail transportation
- 143 water transportation
- 144 road transportation
- 145 communication
- 146 electric utilities
- 147 gas utilities
- 148 water & wastewater facilities
- 149 solid waste utilities

15 industrial / commercial complexes
- 151 industrial park
- 152 office park
- 153 shopping center/mall
- 154 other industrial/commercial complexes

16 mixed (areas where level II uses are mixed with no one use predominating)

17 other urban / built-up land
- 171 outdoor cultural
- 172 outdoor public assembly
- 173 outdoor recreation
- 174 cemeteries
- 179 other urban

2 AGRICULTURAL LAND
21 cropland / pasture
- 211 cultivated land
- 212 hay/rotation/permanent pasture

22 orchards / bush fruits / vineyards & ornamental horticulture
- 221 tree fruits
- 222 bush fruits and vineyards
- 223 ornamental horticulture & nurseries
- 224 tree farms
- 225 sugarbush
- 229 other orchards, etc.

23 confined feeding operations
- 231 livestock
- 232 poultry
- 233 pisciculture
- 239 other confined feeding operations

24 other
- 241 farmsteads
- 242 greenhouses and mushroom houses
- 243 stables and tracks
- 244 sod
- 249 other

3 BRUSH
31 herbaceous
32 shrub and brush
33 mixed

4 FOREST
41 broadleaved forest
42 coniferous forest (generally evergreen)
43 mixed conifer-broadleaved forest

5 WATER
51 streams / canals
52 lakes
53 reservoirs
54 bays / estuaries

Table 9-1 continued.

6 WETLANDS
61 forested wetland
611 tree swamp
612 shrub swamp
62 non-forested wetland
621 emergent
622 meadow
623 aquatic bed
7 BARREN LANDS
71 salt flats
72 beaches and river banks
721 sand beach
722 gravel beach
723 river banks
729 other beaches/riverbanks
73 sandy areas (non-beaches)
731 sand dunes
732 other sandy areas
74 bare / exposed rock
741 rock knobs
742 escarpments
743 shoreline rock outcrop
744 riverbank rock outcrop
749 other bare/exposed rock
75 strip mine / quarry / abandoned gravel pit
76 transitional
77 mixed barren
8 TUNDRA
81 shrub and brush
82 herbaceous
83 bare ground
84 wet
85 mixed
9 PERMANENT SNOW AND ICE
91 perennial snowfields
92 glaciers

Scale

Map scale is the ratio of distance on a map to the corresponding actual distance on the ground. It is a statement of how much distance on the ground a given distance on the map represents. Map scale is expressed in one of three ways:

- *ratio* - e.g., 1:5000 scale, meaning that one unit on the map represents 5000 (of the same) units on the ground. For example one inch on the map represents 5000 inches on the ground. The ratio is said to be a unitless expression of scale because it does not matter what units are used as long as the same units are used on both sides of the expression.
- *equivalent* - e.g., 1" = 2,000 , meaning that one inch on the map represents 2000 feet on the ground.
- *graphic scale* - e.g.,

Note that the graphic scale is the only means of expressing scale that remains accurate if you enlarge or reduce a map (using a photocopy machine, for example). For this reason, if only one type of scale statement is to be used on a map, it is probably wise to choose the graphic scale. However, most helpful, is to use the graphic scale in combination with at least one of the other two forms.

Each of these methods of expressing scale can be easily converted into either of the other two. For example, if the scale is stated as being 1" = 2000' the knowledge that one foot = 12 inches can be used to calculate that this scale can also be expressed as 1:24,000 scale. Similarly, a ruler can be used to measure a graphic scale to determine that 1" = 2,000' and that this, too, represents a scale of 1:24,000. But how can the scale of a map or aerial photograph be determined if for some reason the information isn't provided?

Let's calculate the scale of the Mt. Philo quadrangle and the Mt. Philo orthophoto. Using the map, the east-west road segment from Route 7 to the entrance of Mt. Philo State Park can be measured as 1.53 inches. From a ground survey, we know that the length of this road is 3,060 feet or 36,720 inches. We can calculate that 36,720 / 1.53 equals 24,000, confirming that the map scale is 1:24,000. Using the orthophoto, the same road segment can be measured as being 7.35 inches. We can calculate that 36,720 / 7.34 equals 5003. Therefore the orthophoto scale is 1:5000.

Another way of determining the scale of the orthophoto is by calculating a ratio using the known scale of a map (or airphoto). Divide the length of the road on the orthophoto (7.35 inches) by the length of the road on the topo quad (1.53 inches). Divide 24,000 by the result of this first calculation (4.804) to find the scale of the orthophoto (4996).

$$\frac{7.35}{1.53} = \frac{24{,}000}{x} \qquad x = 4{,}996$$

Note: When calculating the scale of maps and aerial photographs, measure at least two distances, if possible, at right angles to each other. On aerial photos make measurements as close to the center of the photo as possible since scale becomes increasingly distorted toward the periphery of unrectified airphotos.

Keeping in mind that scale refers to a ratio of distance on the map to distance on the ground will help in sorting out the frequently confused terms *"large scale"* and *"small scale"*. 1/5000 is a larger number than 1/24,000 and so a scale of 1:5000 is a larger scale than is 1:24,000. We can say that 1:5000 is large scale and 1:24,000 is small scale. On a large-scale map or photo you see a large amount of detail for a small area. On a small-scale map or photo you see a small amount of detail for a large area. To reinforce this concept, please compare the orthophoto (large scale) to the topo map (small scale) provided in the back of the handbook.

Resolution

Scale is very important in determining *resolution*, or how much detail can be seen or accurately represented on a map. To appreciate the relationship between scale and resolution, look at Figure 9-5, which illustrates the size of a one-acre parcel of land and a ten-acre parcel of

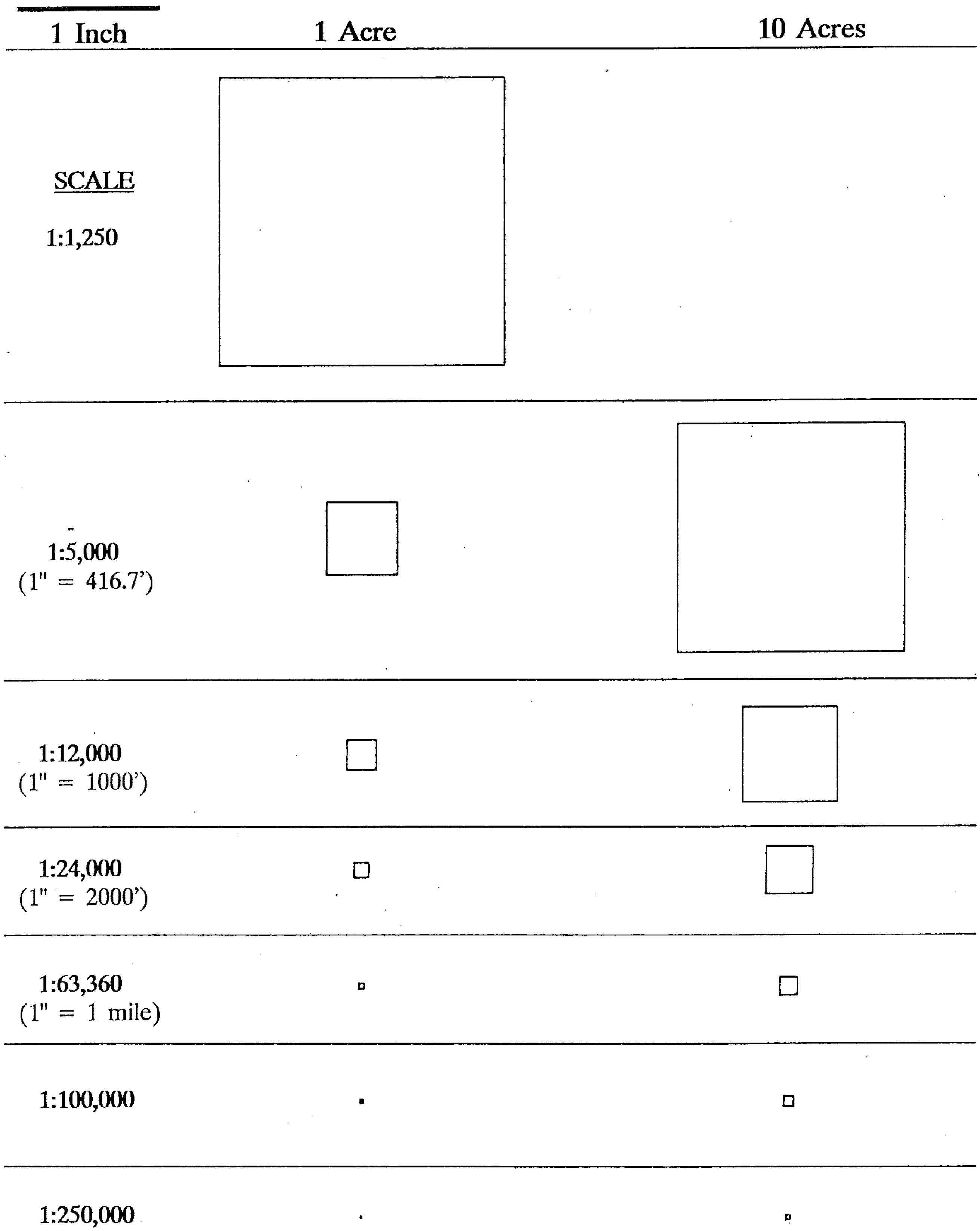


Figure 9-5. The representations of one and ten acres at various scales.

land as they appear at various map scales. The one-acre parcel can be symbolized by a polygon at map scales of 1:24,000 or greater. But at smaller scales the limitations of the human eye and hand, as well as printing techniques, require that the parcel be symbolized as a point. Similarly, for the for the ten-acre parcel map scales of 1:100,000 or smaller require that it be represented as a point rather than as an area.

For each mapping project that involves polygon data, a *minimum mapping unit* must be defined. This is essentially the level of resolution of the information on the map. A polygon smaller than the minimum mapping unit will not be mapped (or will be symbolized as a point). This minimum mapping unit is a function of scale and the purpose of the map, as well as the cartographic process available for producing the map. Generally speaking, one cannot draw polygons smaller than 1/4" on a side with any accuracy. It is difficult to place a legible code or shading pattern within a polygon smaller than 1/4" on a side. If we look again at Figure 9-5 we can see that at 1:12,000 scale, our one-acre parcel is just about 1/4" on a side. If we were producing maps at this scale then we probably would specify a minimum mapping unit (or resolution) of one acre. If we were working at the larger 1:5000 scale, a half-acre resolution might be reasonable.

One must even consider the effect of scale on line width. A 000 technical drafting pen produces a line width of .010 inches or .25 mm. At a map scale of 1:5000, the width of the pen line represents 1.25 meters or 4.17 feet on the ground. But if the scale of the map is 1:20,000 that same pen line represents 5.0 meters or 16.7 feet on the ground.

These purely graphic limitations of minimum mapping unit and line width have implications as we try to represent features at different map scales. We cannot represent the shoreline of Lake Champlain with the same amount of detail at a scale of 1:24,000 as we can at a scale of 1:5000. The following things occur as we attempt to create an accurate but still visually pleasing map at the smaller scale:

- *feature elimination* - Some small islands, coves, and tributary streams will be too small too draw.
- *smoothing* - The fine crenulations of the shoreline will be lost at the smaller scale because our pen line covers a much wider swath of ground.
- *shape abstraction* - Related to smoothing, shapes (e.g., of islands) become more generalized, less planimetrically faithful to true on-the-ground shapes, but nevertheless meaningful at the new smaller scale.
- *aggregation* - Individual small polygons (e.g., patches of orchard on the Island of South Hero) that we could identify on

a 1:5000 scale land use map may be lumped into one larger polygon labeled orchard on the 1:24,000 scale version.

- *combining variables* - Some small polygons may be lost altogether in going from the larger to the smaller scale. If an isolated patch of orchard is surrounded by another land use, e.g., residential, on the small-scale map we may simply represent the area as residential and ignore the fact that, in reality, there is another land use mixed in.

Most of these concepts are intuitive. We don't expect a small-scale map to show us as much detail as the corresponding large-scale map. Nevertheless, mapmakers will receive requests to simply shrink or enlarge a map (by photocopy or other means) and then be the subject of puzzled looks when they try to explain that the accuracy levels change, the classification level will be inappropriate, or line widths will be unacceptable (some disappear when reducing a map, some will become fat worms when enlarging a map). Fortunately for cartographers, there is more to changing the scale of a map than simply running it through a photocopier.

In summary, the content of a map changes as a function of scale. The more detail you want in your final map, the larger the scale at which you must work and, incidentally, the larger the scale your source materials must be. One cannot hope to produce an accurate detailed community land-use map at a scale of 1:5000 by simply enlarging a 1:20,000 scale land use map.

Accuracy

There are two aspects to *map accuracy*: accuracy of location (both horizontal and vertical) and accuracy of classification (or conceptual accuracy). National Map Accuracy Standards (Table 9-2) deal only with the former, positional accuracy. Accuracy is defined in terms of the location of well-defined points (features easily discernible on the map and the ground), and decreases as map scale decreases. It is a statistical notion since only a few points per map sheet are ever tested. The Vermont Map Accuracy Standards are largely based on the national standards.

Classification accuracy is often taken for granted but can still be quantified. Classifying a cemetery as agricultural land on a land use map is an obvious error. However, if a land use map has both a recreational facilities class and a public buildings class, how should a community ice rink be classified? Minimizing classification errors relies heavily on a thorough classification theme with detailed definitions.

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 roads 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 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 map making 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

Table 9-2.

Another aspect of classification accuracy pertains to boundaries. The boundary between a woodlot and a corn field is usually easy to locate and accurately depict on a land use map. The boundary between forest land that grades into brush then into wetland requires a great deal of judgement and well-defined classification criteria to locate in any repeatable way. Accuracy in this kind of situation is often difficult to determine.

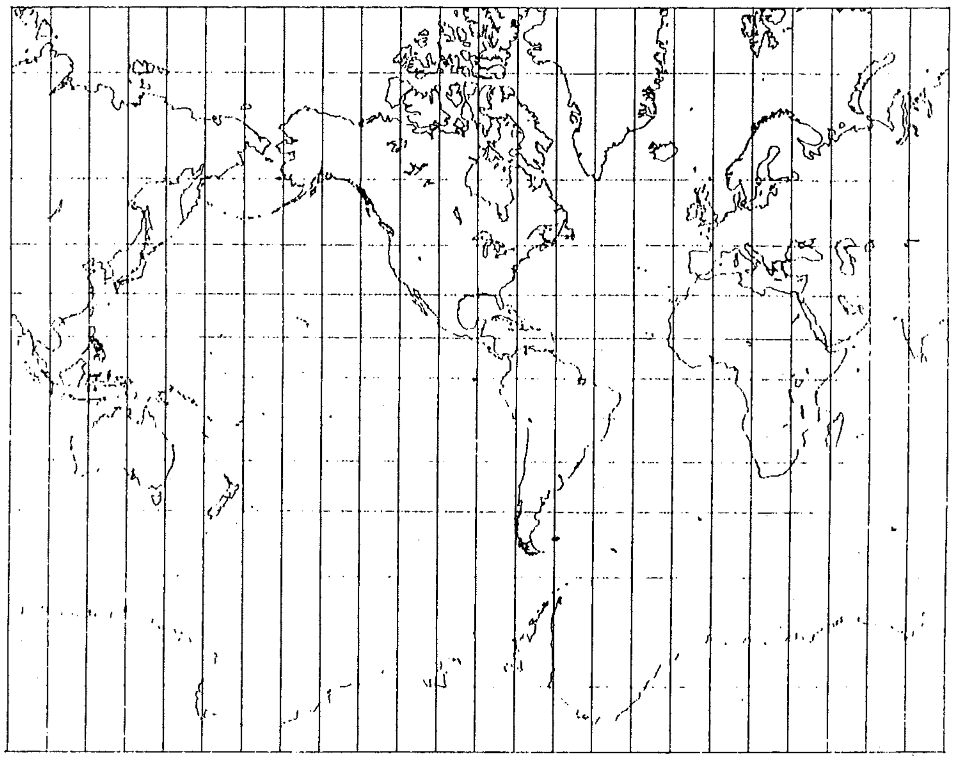
Projections

Map projections are often considered one of the "mysterious aspects" of mapmaking; in fact, the mathematical calculations behind them are complex. However, an appreciation of what map projections are and why they are necessary is important to understanding some of the procedures involved in producing geographically accurate maps and in preparing data for entry into a GIS database.

A *map projection* is a geometric transformation of the earth's surface onto a map surface. It is any one of many approximate solutions to the problem of representing a spherical surface (the earth) on a flat surface (a map). The earth's surface can't be flattened without distorting some geometric property such as direction, distance, area, shape, or continuity. This can be visualized if one considers trying to peel a grapefruit and lay the skin flat on a table. There are infinite ways to peel the grapefruit. The smaller the pieces, the flatter each becomes, thus reducing the amount of distortion in each individual piece but creating increasing problems in approximating adjoining sections.

There is no single best solution to this problem. Each projection is a compromise. Which projection is most useful depends upon the purpose of the map. The cartographer must choose which property (e.g., shape) is to be shown accurately at the expense of the others, or choose a compromise among all the properties. Figure 9-6 shows maps of the world based on two different map projections. The Peters projection accurately represents the relative size of the continents but distorts their shapes. The Mercator projection preserves the shapes but gives a misleading impression of the relative size of the continents.

If the region to be mapped is small, such as a Vermont town, the distortions may not be measurable if an appropriate projection is selected. However, even at the local level, one must at least be aware of map projections because the information to be included on a map or in a community database may be derived from many sources with different scales and projections. Realizing that each projection is a different solution to the challenge of "flattening the grapefruit," we can appreciate why we can't simply overlay information presented to us on different map projections. Features that we expect to line up will not.



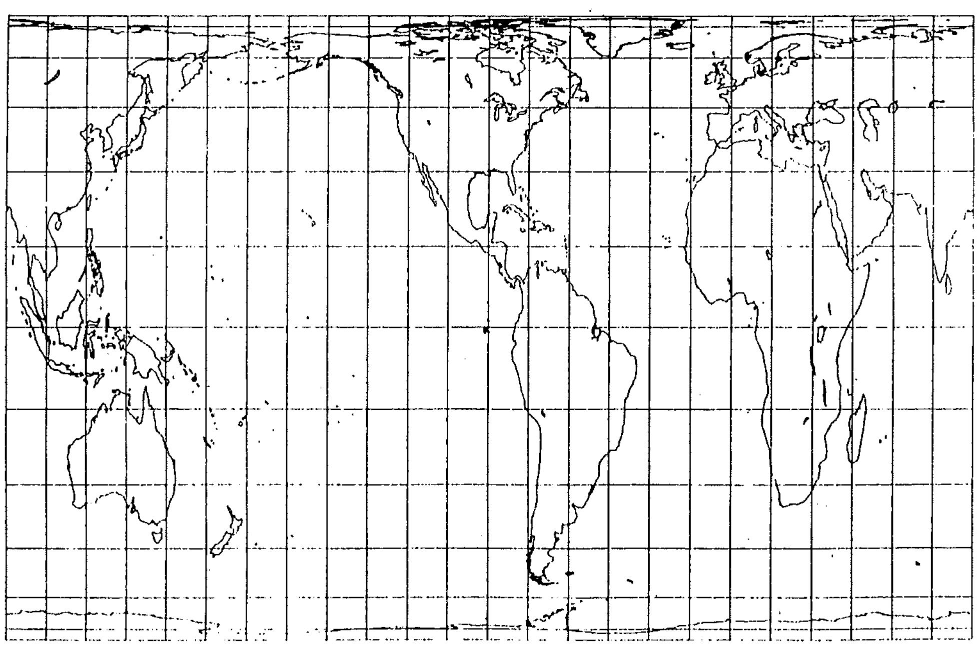


Figure 9-6. Map A is the familiar Mercator projection map. Map B is a Peters projection map.

This can create a problem when one is hand-drawing maps, but is less of a problem when GIS techniques are used to mathematically transform features from one map projection to another (see Chapter 3).

The following are the only three map projections that Vermont communities will routinely encounter in their inventory, mapping, and planning efforts:

- *Polyconic Projection, used on USGS 7.5 minute quadrangles before the late 1950s;*
- *Transverse Mercator Projection, used for USGS 7.5 minute quadrangles between the late 1950s and 1977, also the basis for the Vermont State Plane Coordinate System (see next section); and the*
- *Universal Transverse Mercator Projection used for USGS 7.5 minute quadrangles since 1977.*

We need not be concerned with the derivation and characteristics of each of these projections. For most community purposes, it will suffice merely to note which projection is used on each source map in case future computer transformations are required. The legend for the Mt. Philo quadrangle in the lower left corner indicates that the Polyconic Projection was used in compiling the map.

Coordinate Systems

Features and places shown on a map have a specific location on the earth's surface. *Coordinate systems* are grids of various types that allow us to specify this absolute location. There are three coordinate systems that Vermont communities will routinely use: the geographical grid (latitude/longitude), the UTM grid, and the Vermont state plane grid.

Geographical grid

The *geographical grid* consists of lines of longitude (meridians) running north-south and lines of latitude (parallels) running east-west. Coordinates are measured in angular units of degrees. There are 360 degrees around the earth, 60 minutes in a degree, and 60 seconds in a minute. 0 longitude is defined as being the meridian that runs through Greenwich, England, with locations up to 180 degrees east or west of this prime meridian. The equator is the origin for latitude (i.e., 0" latitude), with locations up to 90 degrees north or south.

The advantage of the lat/long system is that it is universally agreed upon and generally understood. However, calculations are difficult, at best. The neatlines on USGS topo quads are *parallels* on the north and south and *meridians* on the east and west. Each sheet in the 7.5

minute series covers 7.5 minutes of longitude and 7.5 minutes of latitude. (Note that this is not a square!)

UTM grid

The Universal Transverse Mercator or *UTM grid* was devised for use with the Universal Transverse Mercator Projection (see above). It uses metric units (meters, kilometers, etc.) and consists of 60 north-south zones that cover the earth from 80 degrees north latitude to 80 degrees south latitude. Each zone covers 6 degrees of longitude. Zones are numbered going from west to east starting at 180 degrees west longitude. Each zone's true origin is at the intersection of the equator and its central meridian. However, each zone has what is called a false origin which, in the northern hemisphere, is 500,000 meters west of the true origin. The purpose of this false origin is to avoid using negative numbers in the coordinate scheme for each zone.

Vermont has two UTM zones. Most of Vermont is in Zone 18. The section of Vermont east of 72 degrees longitude (parts of the Northeast Kingdom) is in Zone 19. On all recent USGS quads, the UTM grid is indicated by black grid lines at 1,000 meter intervals or by blue tics at 1,000 meter intervals. The tics or grid lines are labeled in black in the map margin with false eastings and false northings. On Vermont orthophotos, the UTM grid is indicated by black broken tics at 500 m intervals along all four borders. The numerical labels are found only along the south and east sides. (Please refer to the Mt. Philo topo quad and orthophoto.)

State Plane Coordinate grid

The *State Plane Coordinate (SPC) System* was created in the 1930s to cover the United States with a flat grid network of constant scale (one of the properties of the transverse mercator projection on which it is based). To minimize scale distortion, the U.S. was divided into 125 zones each with its own projection surface. The zone boundaries are state and county borders. Each zone has a centrally located origin through which passes the central meridian. A false origin is established to the southwest so that all coordinates in each zone will be positive.

On USGS topo quads, state plane coordinates are indicated by black tics along the border of the map at 10,000 foot intervals. On Vermont orthophotos, SPC are indicated with a white grid in 500 meter intervals and with black tics along the border for 2000' intervals. These can be seen on the Mt. Philo topo quad and orthophoto.

Determining Coordinates of a Point

Since most community mapping in Vermont will utilize 1:5000 scale orthophotos and the State Plane Coordinate System, let's look at the Mt. Philo orthophoto to see how exact coordinates for a point can be determined.

Each 1:5000 scale orthophoto represents an area of 4,000 meters by 4,000 meters. The State Plane Coordinate grid appears as a 500 meter grid superimposed on the photo. The orthophoto sheet number is printed in bold on the lower right of each photo. However, this number is derived from the coordinates of the lower left (SW) corner of the photo. For example, the lower left corner of sheet 092196 has the coordinates x = 92,000 meters, y = 196,000 meters (east and north, respectively, from the false origin of the zone).

At the scale of 1:5000, 1 mm on the map corresponds to 5 meters on the ground. (There are 1,000 millimeters in one meter.) Using this relationship, it is easy to determine coordinates for a point directly from the orthophotos. For example, the point marking 294 m elevation near the top of Mt. Philo can be located as follows:

1. *Note the x,y coordinates of the lower left corner of the orthophoto (in meters): $x = 92{,}000$ $y = 196{,}000$*

2. *Locate the 500 meter grid cell containing the feature and determine the distance of its lower left corner from the lower left corner of the orthophoto: $x = 3{,}000$ $y = 1{,}500$*

3. *Using a metric ruler, measure the x and y distances from the left and bottom edges of the 500 meter grid cell, in millimeters. Multiply the number of mm by 5 to obtain meters. 58 mm right and 56 mm up corresponds to: $x = 290$ $y = 280$*

4. *Add up the number of meters obtained in Steps 1 - 3. These are the x,y coordinates in State Plane Meters of the feature:*
   x = 95,290 meters east
   y = 97,780 meters north

The 1:1250 scale orthophotos for urban areas represent an area 1000 meters by 1000 meters. They have a 100 meter grid superimposed on the photo and can be used to obtain even more accurate coordinate information. The procedure is the same as that outlined above but remember in step 3 to multiply the number of mm by 1.125.

Map Design

The content of a map is governed by many factors but, as we discussed above, the primary ones are the purpose of the map and the scale at which it is drawn. Indeed, the purpose should dictate the final scale. Other influences on map design are the quality of the available data and its positional accuracy, the technical production capabilities available, the intended audience, and the conditions of use (in the field, in a car, on a computer screen.

Despite the infinite designs possible, all maps have certain elements in common:

- body,

- title,
- legend,
- georeferencing,
- north arrow,
- scale statement,
- source statement
- accuracy statement, and
- disclaimer.

USGS topo quads, such as the Mt. Philo quad, illustrate all these elements except the disclaimer which was discussed in the preceding chapter.

In the case of the topo quad, the body of the map is set off from the rest of the map by a neatline. The need for a *title* is self-evident, but the mapmaker should consider carefully the size, positioning, and content of the title. It should be brief but sufficient for a user to identify the content of the map and distinguish it from other similar maps. Consider the use of subtitles to elaborate on the main title when necessary.

A *legend* is absolutely critical for map interpretation. A great deal of effort should go into its design so that it is helpful and unambiguous. Class definitions often need to be spelled out in their entirety for the legend to do its job adequately. Where space is limited, there should be a clear reference as to where more detailed class definitions can be found. Symbols should appear in the legend exactly as they do in the body of the map. Shaded boxes must be large enough for the map user to recognize the color and/or pattern being represented. A partial legend appears in the bottom margin of the USGS topo quads. The full legend is available directly from USGS.

Georeferencing may appear as a coordinate grid (as discussed in the previous section) or labeled tic (registration) marks. A statement of the coordinate system and projection used should appear somewhere on the map.

A *north arrow* should also appear on the map, for while it is a convention that north be up, sometimes other elements in the map design dictate that north be some other direction. For some maps it will be important to indicate which kind of north arrow is being used—*true north, grid north, or magnetic north. The USGS topo quad supplies all three north arrows.*

True north or geographical north is the direction to the north pole (the axis of the earth's rotation). Lines of longitude point to true north. Magnetic north is *the direction to the magnetic north pole. The difference between the two is referred to as magnetic declination and varies from region to region. If a map is likely to be used for navigation by compass it is essential that magnetic north and its relationship to true north be indicated on the map. Grid north is the direction the vertical grid lines point on a flat map. The grid may be rotated in relationship to the lines of longitude. This is referred to as grid declination.*

Every map must include a statement of *scale* in at least one of the three forms described previously. Without it, measurement is impossible and it is difficult to comprehend how large a piece of the earth is being represented on the map.

Every map should indicate the *source(s)* of the information on which the map is based and the date that information was compiled. This gives the map user a feel for the authority of the information presented in the map and where to go if more information is desired. In the lower left corner, the USGS quad furnishes source information including the date of the original aerial photography and the dates of subsequent updates.

It is helpful to have some kind of *accuracy statement* on the map. This can be a statement that the map meets *National Map Accuracy Standards*, as on the Mt. Philo quad, or some other published standard if the map, in fact, has been tested and meets those standards. Otherwise, a statement saying that most map features are thought to be within X feet of their true position on the ground is at least a help to the map user.

Map Updating

A map presents a view of a section of the earth at a given point in time. Some features change very slowly (soil types, slope) while others change more quickly (land use, zoning). Some information, to be truly useful, must be updated yearly or even more frequently. Parcel ownership and new parcel boundaries are perhaps the best example of information that requires frequent updating to be helpful in conducting community business. The update process can be time consuming and frustrating when working with traditional paper maps. Much of the map content will remain the same, yet to create an accurate up-to-date map, the entire map will often need to be redrawn. As was explained in Chapter 3, map updating is a much more efficient and accurate process when GIS technology is used to best advantage.

Summary

- Maps, whether hand-drafted or produced by a GIS, should adhere to the principles of cartography.
- Classification schemes need to be exhaustive with well-defined, mutually exclusive categories.
- The choice of map symbols is influenced by the map scale, the purpose of the map, and the means available for map reproduction.
- Map scale determines the level of resolution and accuracy that can be represented on a map.
- A map projection is the representation of the earth's curved surface on a flat map. For data layers to be accurately overlaid they must first be transformed to the same map projection.
- Map coordinate systems provide a means of pinning spatial information to a known position on the earth's surface. Once registered to known earth coordinates, layers of spatial information can be accurately registered to each other.
- All maps should include a title, legend, georeferencing, a north arrow, scale, accuracy, source(s), and a disclaimer.
- To be useful, many maps (e.g., parcel maps) should be updated frequently. Updating is facilitated by GIS.

References

Muehrcke, P.C. 1986. Map Use: Reading, Analysis, and Interpretation. JP Publications, Madison, WI.

Snyder, J.P. 1987. Map Projections"A Working Manual. USGS Professional Paper 1395.

Snyder, J.P. and P.M. Voxland. 1989. *An Album of Map Projections*. USGS Professional Paper 1453.

Glossary

Accuracy : Degree of conformity with a standard, or the degree of correctness attained in a measurement. Accuracy relates to the quality of a result, and is distinguished from precision which relates to the quality of the operation by which the result is obtained.

Alphanumeric: Consisting of both letters and numbers, and possibly including other symbols such as punctuation marks.

Arcs: A portion of a two-dimensional closed figure lying between two nodes. An arc usually represents a continuous common boundary between two adjoining mapping units (e.g., a boundary between wetlands and a lake in a landcover map).

Attributes: Descriptive characteristics, other than location, pertaining to an entity (such as a point or line). Examples: name of a town, length of a street segment, relative poverty of a census tract.

Base Map: Mapped data which seldom change and which is used repeatedly.

Bench Mark: Relatively permanent material object, natural or artificial, bearing a marked point whose elevation above or below an adopted datum is known.

Benchmark: A series of tests for ensuring that hardware and/or software meets user needs.

Bit: In computer sciences, the smallest unit of data.

Buffer Zone: An area of specified distance (radius) around a map item or items.

Bylaws: Zoning regulations, subdivision regulations, or the official map adopted under the authority of 24 V.S.A. Chapter 117.

Byte: Group of eight bits of data (see bit).

CAD/CAM: Computer-aided design/computer-aided manufacturing. Differs from a Geographic Information System in that a CAD/CAM system can only create displays. It cannot analyze or process the base data.

Cartography: Science and art of making maps and charts. The term may be taken broadly as comprising all the steps needed to produce a map: planing, aerial photography, field surveys, photogrammetry, editing, color separation, and multicolor printing.

Central Processing Unit (CPU): The portion of the computer that performs calculations and processes data according to the instructions specified by the software. CPU is sometimes used interchangeably with computer.

Compilation: Preparation of a new or revised map or chart from existing maps, aerial photographs, field surveys, and other sources.

Computerized Data: Data in a digitized format, represented visually as the binary digits "0" and "1", stored in a computer or on a variety of formats ("media")—magnetic tapes, disks, and even paper.

Configuration: The way various computer system devices are electronically connected.

Continuous Data: Interpolatable data with an infinite number of possible values; usually a gradient of values such as elevation or slope (as contrasted with discrete data).

Contour: An imaginary line on the ground, consisting of points that are at the same elevation above or below a specified datum surface, usually mean sea level.

Contour Interval: Difference in elevation between two adjacent contours.

Control Point: A point with a given horizontal position and a known surface elevation to be used in estimating unknown elevations elsewhere in the area to be mapped.

CPU (Central Processing Unit): The part of a computer that performs calculations and processes data according to the instructions specified by the software. CPU is sometimes used interchangeably with computer.

Data: A general term for information, including facts, measurements, classifications or value representations from which conclusions can be inferred.

Data Administration: The duties and responsibilities associated with the overall management, control and documentation of information as an asset of an organization.

Database: Any collection of related information designed, organized, and stored to serve one or many users. A GIS database includes the position and attributes of geographic features that have been coded as points, lines, areas, pixels, or grid cells.

Database Management System (DBMS): A systematic approach to maintaining, accessing, and manipulating database files.

Data Dictionary: Repository of information about the definition, structure, and usage of data. It does not contain the actual data.

Data File: A named collection of logically related data records arranged in a prescribed manner.

Data Format: The way in which data elements are represented and stored in computer records.

Data Input: Entering data into a computer; geographic data is generally entered into a GIS database via a digitizer or a scanner.

Data Item (or Data Element): The smallest unit of named data in a data set.

Data Layer: Refers to data having similar characteristics being contained in the same plane or overlay. Usually information contained in data layer is related and is designed to be used with other layers.

Data Manipulation: Operations that are performed on data to make them more suitable for further processing; to improve their comparability, enhance their retrievability, etc.

Data Processing: The function of creating basic data to provide people with information to support their decisions or actions; sorting, reducing, classifying, calculating, summarizing and subsequently recording such information.

Data Structure: The way data are organized within a computer database. A tabular structure is used by relational database systems.

Data Transfer: The process of moving data from one medium (document) to another. May take place at any time during data processing.

Digital Data: Data in the form of numbers. In geographic processing, both the X and Y coordinates of lines and label characteristics are represented by numbers.

Digital Elevation Model (DEM): A file of terrain elevations that is the digital equivalent of the elevation data on a USGS topographic base map.

Digital Line Graph (DLG): A digital computer file containing lists of point coordinates describing boundaries, drainage lines, transportation routes, and other linear features that is the digital equivalent of the linear hydrographic and cultural data on a USGS topographic base map.

Digital Terrain Model (DTM): A land surface represented in digital form by an elevation grid or lists of three-dimensional coordinates.

Digitize: To encode map coordinates in digital form for use in computer cartography.

Digitizer: A device for converting point locations on a graphic image to plane (x, y) coordinates for digital processing.

Discrete Data: Non-interpolatable data comprised of multiple subjects; each subject is clearly distinct from all other subjects on a map (as contrasted with continuous data).

Disk: A data storage device, similar to a phonograph record, which is magnetized. A "hard" disk is metal and stores large amounts of data. A "soft" or "floppy" disk is made from plastic type material and has limited storage capacity.

Distributed Database: Database with unique components residing in geographically dispersed locations that are linked through a telecommunications network.

Distributed Processing: Access to a computer system by many users at the same time in different locations. Each user has access to his own processor and file storage, and the individual processors may be linked to one another and to a common data base.

Documentation: The description and format of data including definitions, codes, source, date, etc.

Edge Matching: The comparison and graphic adjustment of features to obtain agreement along the edges of adjoining map sheets.

Electrostatic Printer: A device for printing graphic images by placing small electrical charges on the paper so that a dark or colored powder, or **toner**, will adhere in these spots.

Elevation: Vertical distance of a point above or below a reference surface or datum.

Encoding: Converting information to machine readable format.

Export: To transfer data or software from one system to another system.

Feature: An object or aspect of the earth's surface, such as a road, vegetation, or townsite. On a map, a "map feature".

Field: A collection of bytes that represent some discrete unit of information (e.g., in census data, the number of occupants at a certain address would be one field of data for that address).

File: A named set of information; a group of data having similar characteristics.

Flood Plain: Area of low flat ground bordering a stream channel that is flooded when runoff exceeds the capacity of the stream channel.

Floppy Disk: A circular, flexible, relatively inexpensive piece of magnetic material for the storage of digital data.

Format: The arrangement of data in record or file.

Geocoding: Translating geographic coordinates of map units (e.g. lines and points), into X, Y digits or grid cells.

Geographic Data: A collection of data that are individually or collectively attached to a geographic location. (Also spatial data)

Geographic Feature: An entity which occupies a position in space about which locational and descriptive data are stored.

Geographic Information Systems (GIS): System of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, and display of spatially referenced data. (Also spatial information system, land information system, etc.)

Geoprocessing (Geographical data processing): The series of operations performed on or with spatial data in the translation to its ultimate product. Usually refers to digital spatial data handling operations.

Georeference System: An X, Y or X, Y, Z coordinate system that locates points on the surface of the earth as a reference to points on a map. Systems include latitude-longitude, Universal Transverse Mercator, and State Plane Coordinate, etc.

GIS Product: Information stored and manipulated by a GIS system under the guidance of an operator to fulfill a specific need or request not met by the GIS database.

GIS Service: The process of manipulating, summarizing, transforming or outputting GIS data, as performed by a person or a computer.

Graphic Information: The spatial representation of a point, line segment, or polygon on a map in either hardcopy or machine-readable form.

Grid: Network of uniformly spaced parallel straight lines intersecting at right angles. When superimposed on a map, it usually carries the name of the projection used for the map—that is, Lambert Grid, Transverse Mercator Grid, Universal Transverse Mercator grid, etc.

Gri:dased Map - A map on which data are displayed by identically sized grid cells. In a raster-based GIS system, the grid cells may be as small as the pixels used to represent satellite-imagery. The grid-based map is an alternative to a vector-based map, which relies on polygons, lines, and points.

Grid Cell: An individual cell in a grid-based map; the basic unit of analysis used to link the map location to its attribute data.

Groundwater: Water found underground in porous rock strata and soils.

Hard Copy: A permanent image of a map or diagram, for example, a paper map produced on a line printer or pen plotter.

Hard Disk: An inflexible disk with a coating sensitive to magnetic charges.

Hardware: The machinery which constitutes a computer system (as contrasted with the software).

Import: To bring data or software from another system into a system.

Information: Data, a collection of facts. Processed or analyzed data.

Information System: An organized and systematic structure or set of procedures, equipment and personnel supporting the storage, processing, analysis, and output of meaningful data.

Interactive: Refers to a system allowing two-way electronic communication between the user and the computer.

Label: A name or code assigned to the graphic representation of a feature on a map.

Large Scale: A map scale which covers a relatively small area on the ground and shows a large amount of detail. The term "large" refers to the fraction represented by the ratio of map distance to ground distance (e.g. 1:500 scale).

Latitude: Angular distance, in degrees, minutes, and seconds, of a point north or south of the Equator.

Layer: Refers to the various "themes" of data, each of which is normally stored in a separate file in a GIS. Layers are registered to each other by a common coordinate system.

Longitude: Angular distance, in degrees, minutes, and seconds, of a point east or west of the Greenwich meridian.

Mainframe: The central processing unit (CPU) main memory, and control units of a computer, usually housed in one large cabinet or in a number of smaller ones grouped together. The term is only applied to large computers.

Map: Graphic representation of the physical features (natural, artificial, or both) of a part or the whole of the Earth's surface, by means of signs and symbols or photographic image, at an established scale, on a specified projection, and with the means of orientation indicated.

Map, Planimetric: Map that presents only the horizontal positions of features such as waterbodies and civil boundaries; distinguished from a topographic map by the omission of relief in measurable form.

Map, Thematic: Map designed to provide information on a single topic, or group of topics, such as geology, rainfall, or population.

Map, Topographic: Map that presents the horizontal and vertical positions of the features represented; distinguished from a planimetric map by the addition of relief in measurable form.

Map Projection: Any systematic arrangement of meridians and parallels portraying the curved surface of a sphere or spheroid upon a plane.

Menu: A list of options on a computer display allowing an operator to select the next operation to be performed by indicating one or more choices with a pointing device.Merge - To combine items from two or more similarly ordered sets into one set that is arranged in the same order. In a GIS, to splice separate but adjacent mapped areas into a single data set.

Meridian: Great circle on the surface of the Earth passing through the geographical poles and any given point on the Earth's surface. All points on a given meridian have the same longitude.

Modem: A translating device that links a computer terminal to a telecommunications network.

Municipal plan: A framework and guide for accomplishing community aspirations and intentions that is adopted under the authority of 24 V.S.A. Chapter 117.

Mylar: A dimensionally stable plastic material used for drafting. May be clear or frosted on one or both sides.

Natural area: An area of land or water that has unusual or significant flora, fauna, geological, or similar features of scientific, ecological, or educational interest.

Neatline: Line separating the body of a map from the map margin. On a standard U.S. Geological Survey quadrangle map, the neatlines are the meridians and parallels delimiting the quadrangle.

Network Analysis: Analytical techniques concerned with the relationships between locations in a network, such as the calculation of optimal routes through road networks, capacities of network systems, best location for facilities along networks, etc.

Node: A point at which two or more lines meet. Nodes carry information about the topology of polygons.

Operating System: The master control program that governs the operation of a computer system, including: job entry, input/output services, data management, and supervision or "housekeeping".

Origin (of Coordinates system): Defined point in a system of coordinates that serves as a zero point in computing a location according to coordinates.

Orthophotograph: An aerial photograph having the properties of an orthographic projection. It is derived from a conventional perspective aerial photograph by simple or differential rectification so that image displacements and scale differences caused by camera tilt and terrain relief are removed.

Overlay: Data layer, usually dealing with only one aspect of related information, which is used to supplement the data base. Overlays are registered to the base data by a common coordinate system and are usually printed or drawn on transparent or translucent media.

Overlay Analysis: The process of combining spatial information from two or more maps to derive a map consisting of new spatial boundaries.

Parallel: A line of latitude.

Parcel Map: A map or database in which individual properties are the basic units.

Peripheral Device: A device connected to a computer to provide communication or auxiliary functions (e.g., terminal, printer, plotter, digitizer).

Pixel: The smallest unit of information in a grid-cell map, scanner image, or computer graphic image. A contraction of the words "picture element".

Plotter: A device controlled by a computer that creates hardcopy output of graphics for the recording of location information.

Point: A level of spatial measurement referring to an object which has no dimension at a specified scale. Examples include wells, weather stations, and navigational lights.

Polygon: A multisided figure representing an area on a map. Each polygon (area) usually is described by attribute data linked to the polygon's location by the topology of the GIS.

Projection (Map Projection): The manner in which the spherical surface of the earth is represented on a two-dimensional surface; concerned primarily with minimizing distortion in area, shape, distance and direction.

Quadrangle Maps (Quads): A rectangular, or nearly rectangular, area covered by a map. The outline is generally defined by latitude or longitude. Usually refers to USGS topographic maps.

Raster Data: Spatial data arranged in a regular grid pattern in which each unit (or cell) in the grid is assigned an identifying value based on the predominant characteristics within its borders.

Record: All the data fields pertaining to one item or feature (e.g., in census data, a record for a given address would include fields for number of occupants)

Referencing File: The nationwide digital database of planimetric base map features developed by the U.S. Bureau of the Census for the 1990 Census.

Relational Database: A database in which information is stored in tabular format. Related tables are linked by common elements. For example, one table may link street address to parcel number, another table may list the zoning classification for each parcel. A relational database uses the parcel number as the link or "relational item" to produce a zoning classification for a street address.

Relational Join: Establishing relationships from one data table to another, using common data values in both tables. This technique is at the heart of a relational database system.

Relief: Elevation variations of the land or sea bottom.

Remote Sensing: The act of detection and/or identification of an object without having the sensor in direct contact with the object. Includes analysis of aerial photography, satellite imagery, etc.

Representative Fraction: Scale of a map or chart expressed as a fraction or ratio that relates unit distance on the map to distance measured in the same unit on the ground (e.g. 1:500).

Scale: Relationship existing between a distance on a map, chart, or photograph and the corresponding distance on the Earth.

Scanning: Process of using an electronic input device to convert analog information such as maps, photographs, overlays, etc., into a digital format usable by a computer.

Shorelands: Lands surrounding lakes, ponds, reservoirs, rivers, and streams. As defined for shoreland zoning purposes, lands being between the normal mean water mark of a lake, pond or impoundment exceeding 20 acres and a line not less than 500 feet nor more than 1,000 feet from such mean water mark.

Slope: The change in elevation over distance.

Small Scale: A mapping scale which covers a relatively large area and shows a relatively small amount of detail. The term "small" refers to the fraction represented by the ratio of map distance to ground distance. For example, 1:500,000 (one map unit equals 500,000 ground units).

Smart Graphics: Computer programs that combine graphics and data, but are not GIS systems. The "smart graphics", sometimes called "intelligent maps", use a pointer to link graphic elements to attributes, but they do not have a topological structure.

Software: The programs, or instructions, that tell the computer how to respond to specific user commands.

Spatial Data: Information with a locational component.

Spatial Resolution: Measure of the ability to separate closely adjacent objects. Also, the smallest area identified as a separate mapping unit.

State Plane Coordinates: A system of X, Y coordinates defined by the USGS for each state. Locations are based on the distance from an origin within each state.

Terminal: A device for communicating with a computer, usually including a keyboard and either a CRT display or printer.

TIGER: (Topologically Integrated Geographic Encoding and Referencing File - The nation-wide digital data base of planimetric base map features developed by the U.S. Bureau of the Census for the 1990 Census.

Topography: Configuration (relief) of the land surface; the graphic delineation or portrayal of that configuration in map form, as by contour lines.

Topology: The properties of geometric figures, such as adjacency, that are not altered by distortion as long as the surface is not torn. Topological data describe how the the features are connected. For example, nodes (points) represent intersections, lines (arcs) represent the connections between the nodes, and area (polygons) are bounded by lines that are connected and closed.

Topological Overlay: The intersection of two (or more) topologically coded data sets that produces one data set that is uniformly topologically coded with respect to graphic entities and to attribute data.

Transformation: Conversion of coordinates from one referencing system to another.

Universal Transverse Mercator (UTM) grid: Rectangular coordinate system based on the UTM projection, a specific form of the Transverse Mercator Projection which consists (basically) of 60 six degree-wide zones of longitude extending between latitudes 80$ N. and 80$ S.

User Interface: Method by which the human operator communicates with the various database and applications software modules.

Vector: A quantity having both magnitude and direction. As a type of GAIUS, it is a means of coding lines and area information in the form of units of data expressing magnitude, direction, and connectivity.

Vector Structure: A GAIUS data structure that stores information as a sequence of points (vertices) so that each line segment may be though of as a vector. A vector structure can be contrasted with grid-cell or raster data structures.

Wetland: An area that is inundated by surface or ground water with a frequency sufficient to support significant vegetation or aquatic life that depend on saturated or seasonally saturated soil conditions for growth and reproduction.

Workspace: A section of the computer hard drive allotted to a specific user or project, usually containing data files and not programs.

X,Y Coordinate Data: Data digitized by recording Cartesian coordinates which define the location of points.

This glossary was compiled from the following sources:

1.*The GIS Sourcebook*, 1989. GIS World, Inc.

2.*GIS Glossary*, 1989. Vermont OGIS.

3.*Larg:ecale Mapping Guidelines*, 1987. American Society of Photogrammetry and Remote Sensing (ASPRS) and American Congress of Surveying and Mapping (ACSM).

4.*Planning Manual for Vermont Municipalities*, 1987. Vermont Department of Housing and Community Affairs.

Appendix 1 Acronyms

ACSM	American Congress on Surveying and Mapping
AM/FM	Automated Mapping/Facilities
ASCS	Agricultural Stabilization and Conservation Service
ASPRS	American Society for Photogrammetry and Remote Sensing
BAUD	Number of signal elements sent over a communications line in one second
CAD	Computer Assisted Design (or drafting, or drawing, or both)
COE	U.S. Army Corps of Engineers
COGO	Coordinate Geometry
CPU	Central Processing Unit
DBMS	Data Base Management System
DEM	Digital Elevation Model
DLG	Digital Line Graph
DOS	Disk Operating System
DTM	Digital Terrain Model
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FIPS	Federal Information Processing Standards
FLESA	Forest Land Evaluation and Site Assessment
GIS	Geographic Information System
GPS	Global (or Geodetic) Positioning System
LESA	Land Evaluation and Site Assessment
LIS	Land Information System
NCIC	National Cartographic Information Center (USGS)
OGIS	Office of Geographic Information Services (VT)
RFP	Request for Proposal
RPC	Regional Planning Commission
SCS	Soil Conservation Service
TIGER	Topologically Integrated Geographic Encoding & Referencing
URISA	Urban and Regional Information Systems Association
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UVM	University of Vermont
VGIS	Vermont Geographic Information System
VSA	Vermont Statutes Annotated

Conversions

Table 1. Common Map Scales and Their Equivalents

Scale	1 in =_ft	1 in =_mi	1 mi =_in
1:1250	104	0.020	50.69
1:2000	167	0.032	31.68
1:2500	208	0.039	25.34
1:5000	417	0.079	12.67
1:10,000	833	0.158	6.34
1:12,000	1000	0.189	5.28
1:20,000	1667	0.316	3.17
1:24,000	2000	0.379	2.64
1:25,000	2083	0.395	2.53
1:50,000	4167	0.789	1.27
1:62,500	5208	0.986	1.014
1:63,360	5280	1.00	1.00
1:100,000	8333	1.58	0.634
1:250,000	20,833	3.95	0.253
1:500,000	41,667	7.89	0.127

Table 2. Linear Conversions

English - English

1 mile	= 5280 feet
1 mile	= 63,360 inches
1 inch	= 0.02778 yards

Metric - metric

1 km	= 1000 meters
1 m	= 100 centimeters
1 cm	= 10 millimeters

English - metric

1 in	=	2.540 cm
1 cm	=	0.3937 inches
1 ft	=	0.3048 meters
1 m	=	3.281 feet
1 ft	=	30.48 cm
1 cm	=	0.033 feet
1 in	=	0.0254 meters
1 m	=	39.37 inches
1 yd	=	0.914 meters
1 m	=	1.094 yards
1 mi	=	1.609 km
1 km	=	0.6214 miles

Table 3. Area Conversions

English - English

1 sq mile	= 640 acres
1 acre	= 0.001562 sq miles
1 acre	= 43,560 sq feet
1 sq ft	= 0.00002296 acres
1 sq mi	= 27,880,000 sq ft

Metric - metric

1 hectare	= 10,000 sq meters
1 sq km	= 100 hectares
1 sq km	= 1,000,000 sq meters

English - metric

1 sq mi	= 2.590 sq km
1 sq km	= 0.3861 sq mi
1 sq mi	= 259 hectares
1 hect	= 0.00386 sq miles
1 acre	= 0.4047 hectares
1 hect	= 2.471 acres
1 acre	= 4047 sq meters
1 sq km	= 247.10 acres
1 hect	= 107,600 sq feet
1 sq km	= 10,760,000 sq ft
1 sq ft	= 0.0929 sq m
1 sq m	= 10.76 sq ft
1 sq in	= 6.452 sq cm
1 sq cm	= 0.155 sq in
1 sq ft	= 929 sq cm

Appendix 3 GIS Software, Hardware, and Computer Communications

GIS Software

Software is simply a set of coded instructions that tell a computer how to respond to input from the user. There are dozens of different geographic information system software packages available today ranging greatly in both price and functional capabilities. Some of the more widely used GIS software packages include ARC/INFO, ERDAS, Atlas GIS, Intergraph, and SPANS. Regardless of the brand of GIS software used, all include four major components.

Software Components

Data Input Subsystem — The data input subsystem collects and/or processes spatial data derived from sources such as maps and remote sensors. (Several methods of data input will be described in Chapter 7.)

Data Storage And Retrieval Subsystem — The data storage and retrieval subsystem organizes spatial data and tabular data in a form which permits it to be quickly retrieved for analysis. It permits rapid and accurate editing and updating of lines or points, and tabular (descriptive) information.

Data Manipulation And Analysis Subsystem — The data manipulation and analysis subsystem allows the user to combine map layers, aggregate or select sub-sets of one map layer, and specify and create new map layers with new features based on the user-defined criteria (e.g., buffer function). Analysis is largely performed through a database query function that should be straightforward and efficient.

Data Reporting Subsystem — The data reporting subsystem is capable of displaying all or part of the original graphic or tabular information. It also directs plotters and printers to produce hardcopy output (maps and reports).

Although all GIS software can perform the above functions, individual programs vary greatly with regard to the ease and efficiency with which they perform each function.

In addition to the GIS software components, the computer on which the GIS software resides will have an operating system and some special system utilities. The operating system is the basic software provided by the system vendor. It directs all system operations including execution of programs, user access, file security, system accounting, communications, etc. A GIS software package is written to run under a specific operating system. For example, DOS (disk operating system) is the operating system that has become standard on IBM-compatible microcomputers.

GIS Hardware

Hardware is the equipment or machine on which the software programs run. It is available in many configurations, and the options will continue to expand. Regardless of computer size or manufacture, there are some basic functional units that are common to all GIS systems that the user should be know about.

GIS Hardware Components

Processing Unit — The processing unit controls the execution of instructions and manages communication between devices. In the past, processing units have been categorized as mainframe, mini, workstations, and micro-computers (e.g., personal computers or PCs) based on size and processing power. However, with recent advances in computer architecture, clear distinctions between these categories can no longer be made. Also, distributed processing is now possible. This involves multiple processing units and data storage at different physical locations, as distinguished from traditional centralized processing where data resided on, and processing was done within, one host-computer. This is the origin of the term "central processing unit" or CPU.

Mass Storage Units — From microcomputers to large mainframes, all computers use disk drives for storage of data and software. Most microcomputers have hard disk drives (or hard drives) with large storage capacity for active access by the user, and a floppy or disk drive which allows storage of data on a disk that can be removed and transported. Most drives are magnetic, but optical (laser) drives, with higher storage capacity, are becoming available.

Tape Drives — Tape drives magnetically store high volumes of data on flexible tape. They are used for periodic back-up, data archiving, and for shipping data. They are not appropriate for quick on-line access to the data. With microcomputers and workstations, tapes are usually in cassette or cartridge tape format.

Digitizing Station — A digitizing station is a combination of components for entry, edit, and display of primarily graphic data. It consists of a monitor with color display, a digitizing tablet, cursor, and keyboard. There are many possible configurations.

Terminal — The terminal can consist of an inexpensive graphics monitor and keyboard or a personal computer with a mouse for entry of commands using pull-down and on-screen menus. It is used for graphic and tabular query and display as well as browsing and report generation.

Screen Copy Device — Screen copy devices produce hard copy of an image displayed on the graphic monitor. Printers, either color or black and white, are the most common type. They can use electrostatic, ink jet, impact printing, or thermal technology. They provide a quick way of producing draft quality copies of text or graphic images.

Plotters — Two types of plotters are available currently. Pen plotters plot lines from the host computer using multiple line weights and colors. They use cut sheets of various sizes, or rolls of media (paper, mylar) and run at various speeds. Pen plotters produce a high quality output but are not suited for high volume production. (Their production rate is low compared to that of electrostatic plotters.) Electrostatic plotters produce plots in a raster format, meaning that the image is composed of a matrix of dots. Most have an on-board rasterizer which converts vector file from the system database to the raster format necessary for plotting. They usually produce a lower quality image than that produced by a pen plotter. However, high resolution units are becoming available.

Scanners — Optical scanning devices automatically capture and convert text and symbols appearing on a map into a digital raster file. Most scanning systems include software that can then convert the raster information into a vector format (point, line, and polygon features). Although these systems are fast and very accurate they have the drawback of being unable to recognize features or label them. Thus, human intervention is required after scanning to separate text from symbols, to identify feature types, and to label features. Although semi-automated methods are being developed to speed this editing step, the use of scanners is still mostly limited to converting maps that consist of sharply delineated lines and little or no text, such as SCS soils maps.

Computer Communications

For GIS to be an effective tool in Vermont, not only must GIS users talk to one another, but their computers must be able to communicate as well. At the very least they must be able to exchange data so that the effort involved in database construction is not redundant from installation to installation. When exchanging data between different vendor's systems, the user frequently must perform some conversion of data coding and protocols so data is recognizable to each system. To minimize the difficulty in transferring data between facilities, Vermont has chosen a software standard and data exchange format—ARC/INFO. Actual data transfer occurs either electronically or by physically moving data transfer media (usually a disk) from one computer to another.

Media Transfer

Computer tapes, diskettes, or other media can be carried between systems. Data are written on the source system, copied to the tape or disk, and then copied to the destination system. This is a simple and inexpensive way to transfer large volumes of data between computers. It is adequate when transfers are infrequent and when a delay won't be a problem. It does create the potential problem of redundant data storage.

Electronic Transfer

If two computer systems are connected by a network (a system of cables) or by a modem (a device that enables data transfer over telephone lines) data can be electronically transferred from one computer to the other. If a high-speed communications network is installed between computer workstations within a building, interactive (near instantaneous) access to data residing on one system can be accessed by any other. In this case no data files are transferred so there is no redundant storage of data.

Regional Planning Commissions

Addison County Regional Planning & Development Commission
Colonial Drive, RD 1, Box 275
Middlebury, VT 05753
tel: 388-3141

Bennington County Regional Planning Commission
Box 342
Arlington, VT 05250
tel: 375-2576

Central Vermont Regional Planning Commission
26 State Street
Montpelier, VT 05602
tel: 229-0389

Chittenden County Regional Commission
PO Box 108
Essex Junction, VT 05452
tel: 658-3004

Franklin-Grand Isle Regional Planning & Development Commission
140 South Main Street
St. Albans, VT 05478
tel: 524-5958

Lamoille County Planning Commission
RR 1, Box 2265
Morrisville, VT 05661
tel: 888-4548

Northeastern VT Development Association
PO Box 640
St.Johnsbury, VT 05819
tel: 748-5181

Rutland Regional Commission
PO Box 965
Rutland, VT 05701
tel: 775-0871

Southern Windsor Co. Regional Planning & Development Commission
PO Box 88
Windsor, VT 05089
tel: 674-9201

Two Rivers-Ottauquechee Regional Planning & Development Commission
King Farm
Woodstock, VT 05091
tel: 457-3188

Upper Valley-Lake Sunapee Council
314 National Building

Lebanon, NH 03766
tel: (603)448-1680

Windham Regional Planning & Development Commission
PO Box 818
Brattleboro, VT 05301
tel: 257-4547

Other Sources of Technical Assistance

Vermont Office of Geographic Information Services (OGIS)
tel: 828-3447
limited technical assistance available directly to communities but will direct them to sources of services available in the state (RPCs, consultants, UVM, etc.)

Vermont Division of Property Valuation and Review
tel: 241-3500
orthophoto production and distribution; certification of appraisers; assistance to, and training of listers; CAPTAP program

Vermont Deptartment of Housing and Community Affairs
tel: 828-3217 or 1-800-622-4553
provides information and technical assistance on a variety of planning and zoning matters including workshops, newsletters, handbooks, and videos; interpretation of Municipal and Regional Planning and Development Act (Chapter 117)

Vermont Department of Agriculture - Administration Division
tel: 828-2500
technical assistance on agricultural land planning, LESA, and Plan elements pertaining to farmland protection

Vermont Department of Forests, Parks, and Recreation
tel: 244-8716
district foresters provide technical assistance in community planning and management of forest resources, including FLESA

Vermont Department of Environmental Conservation - Solid Waste Division
tel: 244-7831
publications and technical assistance including solid waste management plans and rules, and siting criteria

Vermont Department of Forests, Parks, and Recreation - Recreation Division
tel: 244-8713
assistance with town recreation plans and site-specific planning

UVM School of Natural Resources GIS Program
tel: 656-3324
some over-the-phone technical advice on GIS hardware and software, procedures, and data sources

USDA Soil Conservation Service (SCS)
tel: 951-6795
works with farmers, individual landowners, communities, etc. in identifying and solving erosion problems, identifying valuable farmland, protecting watersheds, etc.

Appendix 5 Data Sources

Local

Permit Files
Assessor's Files
City/town Survey Records
City Street Maps
Facility Maintenance Records (roads, sewers, etc.)
Deeds
Lot and Subdivision Maps
Property Tax Maps
Grand List
Zoning Map
As-built Drawings
School enrollment/districts
Historical Society

State

AGENCY OF ADMINISTRATION

Office of Geographic Information Services
120 State Street
Montpelier, VT 05602
tel: 828-3447
digital data including local information on parcels, soils, roads, political boundaries, etc.; information on sources of GIS services including RPCs and private consultants

DEPARTMENT OF TAXES

Division of Property Valuation and Review
Computer Assisted Property Tax Administration Program (CAPTAP)
tel: 241-3500

Vermont Mapping Program
tel: 241-3507
orthophoto production and distribution

AGENCY OF NATURAL RESOURCES (ANR)

Office of State Geologist
tel: 244-5164
USGS topo maps, Vermont geological maps and bulletins

Natural Resources GIS Project
tel: 244-7340
digital database of all geographic information from ANR

Department of Forest Parks and Recreation
Recreation Division

tel: 244-8713
inventory of trails in state

DEPARTMENT OF FISH AND WILDLIFE

Vermont Natural Heritage Program
tel: 244-7340
lists and maps of natural and fragile areas

Fisheries Access Areas
tel: 244-7331
map of all public fishing and boat access areas

DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Water Quality Division
tel: 244-6951
wetlands publications and wetland inventory maps, river basin plans, inventory of non-point source pollution

Groundwater Management Section
tel: 244-5638
groundwater favorability maps and reports, well and water level records

Floodplain Management Unit
tel: 244-6951
FEMA floodplain maps and information

AGENCY OF DEVELOPMENT AND COMMUNITY AFFAIRS

Dept. of Housing & Community Affairs
Housing Data Bank
tel: 828-3217

Division for Historic Preservation
tel: 828-3326
inventories and/or maps of historic resources and archeologically sensitive areas including "VT Historic Sites and Structure Survey," "VT Archeological Inventory," and "National Register of Historic Places"

AGRICULTURE AGENCY

Agricultural Lands Planning Program
tel: 828-2500
agricultural land inventories

AGENCY OF TRANSPORTATION

Transportation Planning Program
tel: 828-2676
also contact one of nine district offices;

data, reports, studies, and maps including inventory of town highway mileages, and traffic volumes and pavement conditions for state highways

Property Management
tel: 828-2093
locations, dimensions, etc. of State owned property including rights-of-way

DEPARTMENT OF HEALTH

Research, Statistics, and Data Processing
tel: 863-7300
data on population, birth rate, death rate, vital statistics, and migration patterns in Vermont since 1955

Public Water Supply Program
tel: 863-7220
maps of public community water systems source protection areas

UNIVERSITY OF VERMONT (UVM)

School of Natural Resources - GIS Program
tel: 656-3324
various digital data layers for sections of the state; also available through OGIS

Federal

MAPS AND DIGITAL DATA

Earth Science Information Center
c/o Documents/Map Department
UVM Bailey-Howe Library
tel: (802)656-2503

Eastern Mapping Center
ESIC-USGS
507 National Center
Reston, VA 22092
tel: (703)860-6045

AERIAL PHOTOGRAPHS AND SATELLITE IMAGERY

EROS Data Center
USGS
Sioux Falls, SD 57198
tel: (605)594-6507

ASCS Aerial Photography Field Office
2222 West 2300 South
PO Box 30010
Salt Lake City, UT 84130
tel: (801)524-5856

U.S. Geological Survey (USGS)
National Mapping Division
508 National Center
Reston, VA 22091
tel: (703)860-6509

LAND USE/LAND COVER, TRANSPORTATION, HYDROGRAPHY, ELEVATION

USGS ESIC - Eastern Mapping Center
507 National Center
Reston, VA 22092
tel: (703)860-6045
diigital planimetric data (hydrography, transportation, hypsography, political boundaries, etc.):
National Cartographic Information Center
507 National Center
Reston, VA 22092
tel: (703)860-6045

GEODETIC & ELEVATION

National Geodetic Information Center
Rockville, MD 20852
tel: (301)443-8631

National Geophysical Data Center NOAA E/GC1
325 Broadway
Boulder, CO 80303
tel: (303)497-6474

GEOCODES FOR NAMED PLACES

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
tel: (703)487-4807

POPULATION AND RELATED STATISTICS

Vermont Census Data Center Program
tel: (802)828-3211
acts as repository of Census data in Vermont; will maintain town level database on population, housing, income, local property values, and taxes for TIGER files and other data

Customer Services Branch
Data User Services Division
Bureau of the Census
Washington, DC 20223
tel: (301)763-4100

SOILS

USDA Soil Conservation Service (SCS)
Essex Junction tel: (802) 951-6423
Burlington tel: (802) 951-6795
Middlebury tel: (802) 388-6746

USDA Soil Conservation Service (SCS)
National Cartographic Center
P.O. Box 6567
Ft. Worth, TX 76115

FLOODPLAIN MAPS AND STUDIES; FLOOD INSURANCE PROGRAM

Federal Emergency Management Agency
FEMA Flood Map Distribution Center
6930 (A-F) San Thomas Road
Baltimore, MD 21227-6227
tel: (800)333-1364

NAVIGABLE WATERWAYS, WETLANDS, AND WATERSHEDS

US Army Corps of Engineers (COE)
Essex Junction Field Office of the New England Division COE
tel: (802)951-6755

WATER

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
tel: (703)487-4807

WATER QUALITY, FLOW, DISCHARGE, STORET FILES

Environmental Protection Agency (EPA)
Office of Water & Hazardous Materials
401 "M" Street, S.W.
Washington, DC 20460
tel: (202)426-7792

NATIONAL WETLANDS INVENTORY

U.S. Fish & Wildlife Service
National Wetlands Inventory
9720 Executive Center Drive
St. Petersburg, FL 33702
tel: (813)893-3624

WILDLIFE

Migratory Bird & Habitat Research Lab
U.S. Fish & Wildlife Service
Laurel, MD 20811
tel: (301)776-4880 Ext. 281

FOREST SERVICE TERRAIN DATA, ORTHOPHOTOS, BASE-MAPPING

USDA Forest Service
Engineering Staff, Room 1109-RPE
P.O. Box 2417
Washington, DC 20013
tel: (703)235-8184

HAZARDOUS WASTE SITES

Environmental Protection Agency (EPA)
Office of Planning & Management
Washington, DC 20460
tel: (202)755-0811

NATIONAL RAIL NETWORK DATABASE

Federal Railroad Administration
Chief, Information & Systems Division
400 7th Street, S.W., Room 8300A- (RRP-22)
Washington, DC 20590

Appendix 6 Funding Sources

Act 200 Special Municipal Planning Grants

contact: Vermont Dept. of Housing and Community Affairs
tel: 828-3217
up to $25,000 is available for projects whose "special" designation and support are well demonstrated

Housing and Conservation Trust Fund

contact: Vermont Housing and Conservation Board
tel: 828-3250
loans and grants for projects that include both affordable housing and conservation; feasibility studies and organizational development to undertake same

VT Community Development Program

contact: Vermont Dept. of Housing and Community Affairs
tel: 828-3217
planning grants of up to $30,000 can be used for mapping, inventory, and GIS

Federal Land and Water Conservation Fund

contact: Division of Recreation, Vt. Dept. of Forests, Parks, and Recreation
tel: 244-8714
grants to municipalities for acquisition of land and development of facilities for outdoor recreation

Appendix 7 Professional Societies

American Congress on Surveying and Mapping (ACSM)
5410 Grosvenor Lane, Suite 100
Bethesda, MD 20814
tel: (301)493-0200

American Planning Association
Box 97774
Chicago, IL 60578
tel: (312)955-9100

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

Association of American Geographers (AAG)
1710 16th Street NW
Washington, DC 20009
tel: (202)234-1450

North American Cartographic Information Society
6010 Executive Blvd., Suite 100
Rockville, MD 20852
tel: (301)443-8075

Urban and Regional Information Systems Association (URISA)
900 2nd Street NE, Suite 304
Washington, DC 20002
tel: (202)289-1685

Appendix 8 Vermont GIS Consultants

Associates in Rural Development
P.O. Box 1397
Burlington VT 05402
Scott McCormack
658-3890

BSC
425 Summer Street
Boston MA 02210
Peter Ring
617 345-4098

Cartographic Associates, Inc.
P.O. Box 267
Littleton NH 03561
Pam Shores
603 444-6768

CDM, Inc.
One Center Plaza
Boston MA 02108
Gile Beye
617 742-5151

Chenette Engineering
50 State Street
Montpelier VT 05602
Bernard Chenette
229-1442

Dubois & King
P.O. Box 339
Randolph VT 05060-0339
Dan Stover
728-3376

East Coast Mapping
123 Sheep Davis Road
Concord NH 03302-0431
Wilfred Keyser
603 225-1091

Green Mountain Geographics
P.O. Box 2171
South Burlington VT 05407
Gary Smith
656-3092

Harvard Design and Mapping Company, Inc.
80 Prospect Street
Cambridge MA 02139-2503
Jim Aylward
617 345-0100

IEP Corporation
P.O. Box 780
Northboro MA 01532
Lester Garvin
508-393-8558

Land Systems Inc
P.O. Box 496
Greenland NH 03840
Gene Roe
603 436-9538

microDATA
40 Portland Street
St. Johnsbury VT
Bruce Heinrich
748-5503

Ed Moore Computer Services
P.O. Box 63
Underhill Center VT 05490
Ed Moore
899-4788

North Country Environmental & Forestry
Management & Planning
Main Street
P.O. Box 427
Concord VT 05824
Jim Wood
695-8897

Pinkham Engineers, Inc.
431 Pine Street
Burlington VT 05401
Larry Young
658-5588

Resource Systems Group
Box 1104
Norwich VT 05055
Colin High
649-1999

James W. Sewall Co.
P.O. Box 433
Old Town ME 04468
Mark Jadkowski
207 827-4456

TWM Northeast
2A Williston Park
P.O. Box 784
Williston VT 05495
Tim Cowan
879-7733

As of September 14, 1990. Appearance on this list does not constitute endorsement by OGIS.

Applying the Concepts

Exercises illustrating concepts introduced in the text

1. Needs Assessment

a. Compile a list of the commissions, committees, departments, working groups, citizen groups, etc. in your community that use geographic information and how they use it to carry out their mission.

b. Using Figure 6-1 as a model, devise a questionnaire that could be distributed in your community to determine what geographic data should be included in a GIS database.

c. What do you see as a pressing need in your community that better spatial information would help solve (e.g., less conflict between residential and commercial uses)? What maps and other data would you assemble to address this problem?

2. Linking Attribute and Spatial Data

a. Using a copy of a tax map sheet from your community, sketch in a proposed right-of-way for a bike path. The right-of-way should be approximately 20 ft. wide. Make a list of all the parcels over which the proposed bike path will pass and all the parcels which abut the proposed bike path. Using your community's grand list, find the owners of these parcels and their mailing addresses so they can be notified for future public hearings.

b. From your community's public works department or roads supervisor, ascertain what kinds of construction and maintenance records are kept. How could this information be organized into a tabular format and linked to locations on a map?

c. Using any existing map (or an orthophoto) of your town to aid your thinking, compile a list of infrastructure information that would be helpful for planning purposes in your town (e.g., roads, culverts, bridges). Separate items in your list into point, line, and polygon features according to the way they would be represented on a 1:5000 scale map (i.e., at the scale of the orthophoto included in this handbook.) For each item, make a list of information you would like to store about that item (e.g. ,culverts: material, diameter, date cleaned, condition).

3. Analyzing Maps

a. Using a small portion of a soils map from an SCS county soil survey devise a new soils map that shows areas of slight, moderate, and severe limitations for septic tank disposal fields. You will need to refer to a table in the soil survey that rates each soil for its potential for various kinds of community development.

b. Using the same soil map, devise a more generalized map by aggregating individual soil polygons according to slope or soil group. I.e. lump all polygons with the same slope into one class regardless of soil type (a slope map), or lump all polygons with the same soil type into one class regardless of slope.

c. Consider how laborious 3a and 3b would be to do on a town-wide basis. Can you see how having the soils information computerized would facilitate these analyses?

4. Map Scale

a. At a map scale of 1:5000, one inch = ____ feet?

one centimeter = ____ meters?

b. If 1" = 1000 feet, what is the map scale expressed as a ratio?

c. Draw a scale bar representing a scale of 1:63,360.

d. Using a 1:5000 scale orthophoto of your community for comparison, calculate the scale of various maps that are used in your community (e.g., base map, highway map).

5. Map Coordinates

a. What are the state plane coordinates (in meters) of the four corners of the Mt. Philo orthophoto?

b. Find the small pond to the northeast of Mt. Philo drawn in purple on the Mt. Philo USGS topo quad. What are its coordinates in terms of:

- latitude/longitude

- UTM meters

- state plane meters?

Now calculate the coordinates of the pond using the orthophoto. Do the results of the two methods agree?

c. What is the elevation of the pond?

Index