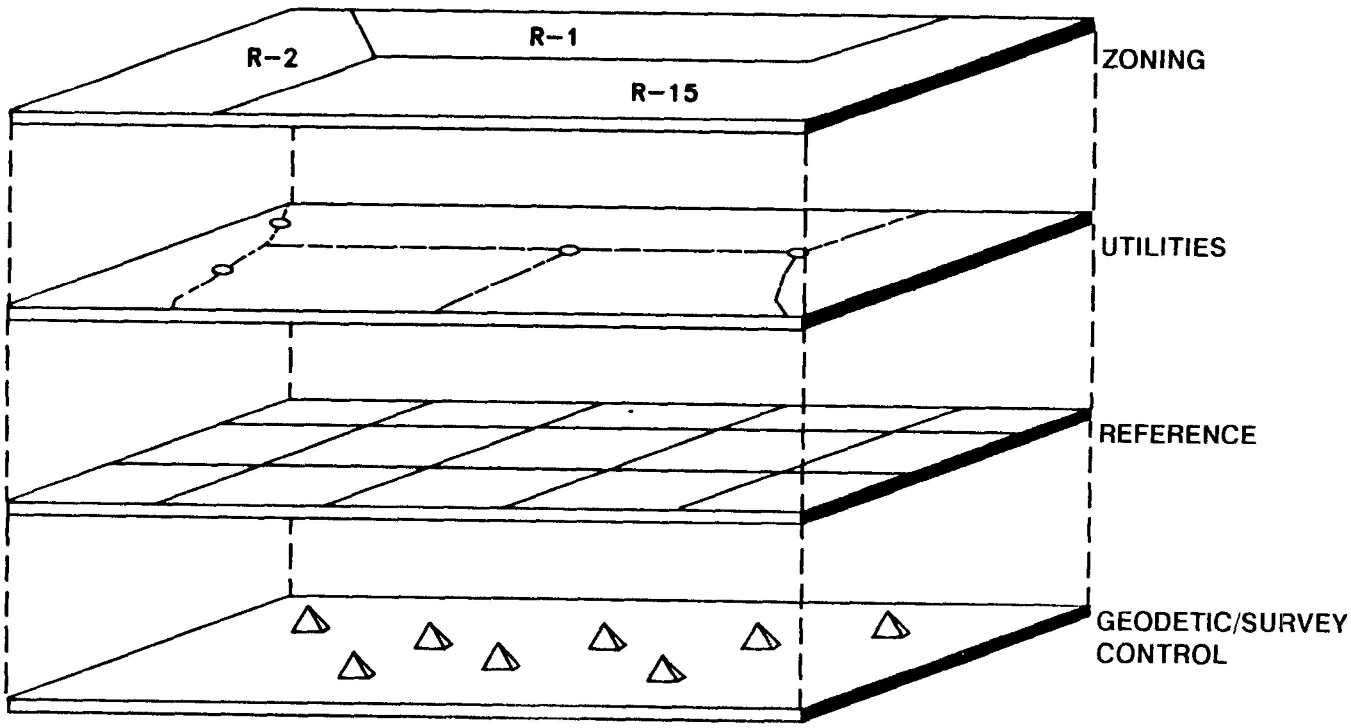
Open-File Report 89-39

GEOGRAPHIC INFORMATION SYSTEM INDEX FOR THE STATE OF TENNESSEE



Prepared by the
U.S. GEOLOGICAL SURVEY

in cooperation with the
TENNESSEE STATE PLANNING OFFICE and the
TENNESSEE COMPTROLLER OF THE TREASURY

USGS
science for a changing world

A standard naming convention for coverages should also be adopted within the State government. Because of differences in the number and type of characters required by the computer systems involved, the managers of each system need to reach an agreement concerning this. This should also be a consideration as more state agencies acquire GIS systems. At present, a coverage for Lake County roads might be called LKRDS on one system, HWY095 on another, and R001.880426 on another.

A standard organizational scheme also should be developed. For instance, each State GIS site should organize its coverages using the same method (for example, by county or quadrangle or State Plane coordinate area). This would enhance the transfer of a coverage from one system to another.

DATA COMMUNICATIONS TECHNIQUES

Data from one computer can be transferred to another by a variety of techniques. The most common technique for mainframe or minicomputers is magnetic tape. Magnetic tapes can generally be written to various technical specifications, and can also generally be read if certain criteria are known. The basic criteria are:

1. bits per inch (bpi) - usually 800, 1600, or 6250

   For data transfer the tape drive at the source machine must be capable of writing a tape at the same bpi required for the receiving machine.

2. tape protocol - usually ASCII, EBCDIC, or BCD

   For data transfer the source machine must have the appropriate software for writing a tape in a protocol that can be read by the receiving machine.

3. logical record length - a fixed or variable number

   The logical record length depends upon the record length of the data. The data can either have a fixed length or a variable length. Fixed- length data is generally much easier to transfer.

4. block size - varies

   The block size is an indication of the number of logical records grouped together. If 10 logical records that are 80 characters long are put together as a block of data, then the block size is 80 x 10 = 800. Many systems require a blocking factor which is the block size divided by the logical record length, in the example above 800 / 80 = 10. The sender must let the receiving user know either the block size or the blocking factor.

5. labeled or unlabeled - Many computer systems write information in the form of a label at the beginning of each file. Sometimes another machine cannot read the label. Most tape transfers are sent as unlabeled to avoid this problem.

Another form of data transfer is from one mainframe or mini-computer to another by means of synchronous telecommunication lines. Synchronous mode communications normally require a more sophisticated modem to recover "clock" signals from the data on the telephone lines. The data are transmitted in blocks, usually eight bits at a time, over data-quality telephone lines at baud rates ranging from 4800 to 56,000. This form of communication is much faster and also more expensive. The two computers must utilize remote job entry procedures and must be configured as look-a-like units with one serving as the host computer and the other serving as the remote unit. Some type of emulation protocol is required to reside on each.

The most common method for transferring data from mainframe or minicomputers to micro or personal computers is by means of terminal emulator software and file transfer protocols. Most terminal emulator and file transfer software must reside on both the sending and receiving device. The most common file transfer protocols are Kermit and Xmodem. Numerous commercial software packages have been written which incorporate both terminal emulator and file transfer protocols. The terminal emulator software makes the mainframe or mini-computer think the micro or personal computer is just another terminal for sending or receiving data, and the file transfer protocols allow for reading data from the input buffers and writing it to disk in a logical manner.

This form of communication requires that asynchronous lines be available at the mainframe or mini-computer. In asynchronous mode the characters travel individually down the line as they are keyed in by the user. Usually voice quality phone lines are sufficient in this mode at transmission rates of 300 to 1200 baud.

Data can also be transferred via a network. A network can be simply personal computers and terminals connected to a mainframe or mini-computer by means of co-axial cable in a localized area (Local Area Network, LAN) or can be several computers connected together over dedicated, leased telephone lines (Wide Area Network, WAN). Considerable expertise is required for either a LAN or WAN. Specialized software is required for each.

The type of data transfer selected depends upon the equipment and software available at each site, the frequency of data transfer, and the amount of funding available to establish a communication link. As technology continues to develop and as demands for better communications are placed upon vendors, the dependency upon the type of equipment and software at each site is becoming less important, and the cost is decreasing.

MAP COVERAGE RETRIEVALS FROM THE GIS INDEX DATA BASE

The GIS index data base currently resides on a 9955II Prime super-minicomputer operated by the Tennessee District of the USGS, WRD. The data are stored in an INFO relational data base.

The data base is menu-driven and is capable of producing output reports based upon several reselection criteria: agency-id, county, quadrangle, city, and hydrologic unit code.

A county coverage, a 7.5-minute quadrangle coverage, and a hydrologic unit coverage were created to facilitate retrieval of available layers for each of these political or geographic areas. For instance, once a user connects and logs into the USGS computer system, typing TENNIS (the ancronym for TENNessee Information System) displays a menu with several options. By selecting option 5, TENNESSEE GIS QUAD PLOT, a plot of all of the 7.5-minute quadrangle maps which cover Tennessee is drawn on the screen (a Tektronix 4107 or 4207 terminal must be used) and the user is prompted for a quadrangle identifier. The plot displays the quadrangle name and identifier in the center of each quadrangle. After zooming in on the area of interest, the user enters the quadrangle identifier. The number of coverages available for the quadrangle is displayed and a report of each coverage is displayed. Similar reports for listings by county or hydrologic unit may be obtained by selecting option 4 or 6, respectively, from the TENNIS menu.

Computer to computer access is available over asynchronous communication lines, 1200 baud modems, and a regular phone line. Computer access must be first established by means of a Cooperative Memorandum of Understanding. Presently no funding is available for sustained access to the data base or for data base maintenance and update. Use of the data base would, therefore, be at the discretion of the District Chief. For additional information contact:

District Chief
U.S. Geological Survey, WRD
A-413 Federal Building
Nashville, TN 37203
(615) 736-5424

Hard copy data may also be obtained from the above location.

OBSERVED TRENDS AND NEEDS OF GIS SYSTEMS IN TENNESSEE

Trends

Several GIS trends have developed in Tennessee. Most of the trends are related to the size of the geographic areas being studied and to different agency needs.

One of these trends is that universities and agencies that are concerned with natural resources typically use USGS 7.5-minute quadrangle maps as their base coverages. This may be dictated by historical precedence or is possibly because the USGS has many of the maps already in digital form. Within these organizations, however, there appears to be a need for studying large areas (a river basin, for example). Political boundaries are generally of little importance, and accuracy within several yards is acceptable.

On the other hand, county and municipal GIS users typically use property tax maps as their base coverages. Their area of interest generally lies within a fixed political boundary. They are also normally concerned with greater accuracy (2-foot contour intervals or 3-foot accuracy, for example) for utility engineering purposes. Most of the municipal GIS users, therefore, conduct their own aerial surveys from which the data is digitized. This is an expensive procedure that is approximately 25 to 50 percent of the GIS budget for the first 5 years. Another result of the need for greater accuracy for engineering purposes is that the GIS equipment and software normally requires CAD capabilities.

As a consequence, two sets of base maps are being developed by GIS users. One is based upon the USGS quadrangle maps and another is based upon county and municipal digital aerial photography with property tax boundaries being one of the basic coverages.

Another trend is that municipal and county governments are using a variety of divergent GIS software. Eight GIS systems exist at the city and county level. All are different software packages.

County and municipal GIS systems

AGENCY-ID	AGENCY-NAME	GIS SOFTWARE
C093A	Knox County Government	Intergraph
C149	Rutherford County Planning Commission *	Atlas/AGIS, remote-sensing
C157A	Memphis and Shelby County Planning and Devel.	Geographic Data Management System
M001	Memphis Light, Gas, and Water	Geographic Facitlities Management System
M002	City of Chattanooga	McDonnell Douglas
M003	Nashville Metro Water Services GIS	Synercom
M004	Johnson City Transit Headqaurters	Autometric AutoGIS
M021	City of Dyersburg	AutoCAD

* Coverages are located on Middle Tennessee State University computer system.

Partially because of the expense of a GIS system, some of the municipal and county governments are seeking to develop projects with surrounding counties. This may result, in time, in regional GIS systems of several types.

In educational institutions the trend is toward the use of Environmental Systems Research Institute's ARC/INFO software. This software has recently been purchased by four institutions. Middle Tennessee State University, the remaining educational institute with a GIS, has been using an Atlas/AGIS system for several years.

Educational institutions that use ARC/INFO

AGENCY-ID	AGENCY-NAME
S002	Tennessee Technological University
S008	University of Tennessee, Knoxville
S012A	Memphis State University, Department of Civil Engineering
S012B	Memphis State University, Department of Geography

From the technological side, the trend is toward using enhanced personal computers or workstation systems although few micro computers are currently running GIS within the State. Small computers have become increasingly more powerful, and disk size and cost have decreased while storage capacity has increased. The result is that small agencies with limited budgets can now procure a personal computer- or workstation-based GIS for about $20,000 to $50,000.

Needs

Within the GIS community as a whole there are some needs which should be met to enhance all efforts. One of these needs is for designation of which agency becomes responsible for certain coverages. At the present time, several agencies might be maintaining a roads coverage. The roads coverage at one site might have been digitized from a 1948 USGS 7.5-minute quadrangle map, at another from a 1984 aerial photograph, and at another the digital data may have been procured from the NMD. Perhaps none of the above coverages truly represents the roads. There is a need for definitive (most reliable and complete) coverages, and for placing the responsibility for these coverages upon specific agencies.

Another need is for a statewide GIS newsletter. Many organizations operate almost exclusively on their own without any exchange of information. Other organizations publish a newsletter but only for their immediate area. In addition, several small user groups within the State have developed newsletters, but these are distributed only to their members. A Statewide newsletter would help to keep all GIS users within Tennessee aware of any new map coverages or any hardware or software development.

There is also a need to be able to rapidly ascertain who has particular map coverages, how easy it would be to obtain the coverage, and how much cost would be involved in obtaining the coverage. A few of the larger municipalities have established marketing departments for this purpose, but for the most part, the only way of obtaining this information is to consult the data base established for this project. The useful lifespan of this data base is limited considering that more mapping coverages are created each week. Provision has not been made for the continuing update of the data base.

A possible solution for meeting the needs just described would be the creation of a mapping center. General reponsibilities could include designating the responsibility of definitive coverages, publication of a Statewide newsletter, and maintenance and updating of the existing data base for inquiry purposes. A mapping center could also host an annual meeting of GIS users for the exchange of ideas, procedures, and technological information. Other responsibilities might include resolution of, or at least assistance with, technical problems such as telecommunications, transfer of data from one system to another, and so forth.

Various states have established or attempted to establish such centers. The success of mapping centers in those states has largely been dependent upon the enthusiasm of the committee members which serve as staff (usually an additional assignment along with their other duties). To resolve the problem of inadequate, full-time staffing, funding should be made available to provide a permanent staff for a mapping center, whose sole responsibilty would be to run the center on a full-time basis with appropriate equipment and support. In the initial phase, this could be two people. If the need or desire grows the staff could be increased.

Funding for such a center could be provided by the state, federal, municipal, or county agencies that would profit from such a center. Many different schemes for designing and implementing such a center would be possible. The main point is that some type of mapping or GIS center is needed.

SUMMARY

In 1987, because of the increasing use of GIS, the USGS, TSPO, and the Tennessee Comptroller of the Treasury entered into a jointly funded project to conduct a survey of public GIS users in Tennessee. The following tasks were accomplished as a result of that project:

1. A GIS survey was conducted and documented. The survey included information about existing map coverages, location-specific data bases, uncomputerized data bases, existing computer equipment, existing GIS systems, system to system conversion software, and potential GIS sites.

2. A GIS index computerized data base was created for entering, storing, and retrieving data collected from the survey.

3. General standards were defined for digitized data.

4. Several communication techniques for tranferring data from one site to another were described in general terms.

5. A county coverage, a 7.5-minute quadrangle coverage, and a hydrologic unit coverage were created to facilitate retrieval of available layers for each one of these political or geographic areas.

Due to the extensive quantity of data, publication of the entire GIS Index Data Base is not feasible. Information in the form of magnetic media, direct computer access, or hard copy may be obtained at the discretion of the District Chief from U.S. Geological Survey, WRD, A-413 Federal Building, Nashville, TN 37203, (615) 736-5424.

At this time, GIS efforts across the State are quite fragmented. A variety of equipment and software are being used across the State, primarily by large municipal and county governments and resource agencies. Other than the occasional formation of user groups, there is no organized, planned strategy for GIS development on any other scale than that of each individual GIS site.

Within the state government itself, there are three possible ways of approaching the development of GIS's. Each has its advantages and disadvantages.

The first option is for the state government to decide upon one type of GIS software and hardware for use by any of its agencies. This could be one large, centralized system or several smaller systems. Because of storage size and CPU limitations, the use of several smaller systems would probably be more feasible. The main advantage to having one type of GIS software and hardware is obvious: total compatibility. The disadvantages would be (1) one GIS software package might not meet the various needs of different agencies, (2) since more than one system already exists, one would have to be salvaged and all coverages converted, resulting in loss of money and manpower, and (3) the cost and time involved in selecting one system would be substantial.

A second option is for the State to procure, develop, or arrange for the development of system-to-system transformation software so that digital data can be transferred with minimal effort between the two major existing systems (Department of Transportation Intergraph and Tennessee Wildlife Resources Agency Arc/Info). Then other agencies could select any GIS vendor that meets their needs and permits their data to be used by both existing systems and vice versa. In brief, the State would allow different GIS systems provided data can be fully shared among agencies. The main advantage to this is the reduction of duplicated work. The disadvantage is that transformations between two or more systems do not generally result in 100 percent data transfer. Also, the more systems involved, the greater the complexity.

A third option may be to allow GIS efforts to continue to develop in the fragmented manner in which they are currently going but with some guidelines or centralized authority. The term "fragmented" tends to have a negative connotation. However, "fragmented" GIS efforts have some definite advantages: (1) each agency is able to meet its needs with whatever software and hardware it thinks is most appropriate, (2) diversity of software and hardware could generate a higher degree of functionality (one system might be able to do something another cannot), and (3) if one or more GIS vendor leaves the market, other systems are still up and running. Of course, there are the disadvantages of: (1) duplicated work, (2) software and hardware incompatibility, and (3) lack of control, organization, or authority.

In summary, GIS can indeed be useful, by reducing long term mapping costs, by improving mapping efficiency, and by enhancing decision-making, but it is not an absolute necessity. "Lukewarm" approaches to establishing an effective GIS do not generally work. GIS efforts do not pay off on a short term basis; to be cost effective they should continue across changes in administration and should be funded for a sufficiently long period of time to allow for pay back.

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APPENDIX A: GIS survey forms

A D D R E S S   F O R M

AGENCY ID: ___ | ______ | ___
Type | Agency# | Suboffice

Type: S - STATE
F - FEDERAL
C - COUNTY
M - MUNICIPAL

(A unique identification number is assigned for each organization.)

COUNTY CODE ______

AGENCY: Name ____________________

Address ____________________

____

____________________ City | ____ State | ______ Zip Code

CONTACT: Name ____________ Last | ____________ First

PHONE: _____ Area Code | _____-_____

COMMENT:

____

Figure 1.--GIS survey form for collecting address information.

MAP FORM

Do you use maps? Y N

What type of maps do you use? ______________________________

What do you use the maps for? ______________________________

Where do you get your maps? ______________________________

Medium: ______________________________

Scale: ______________________________

Extent: ______________________________

Main Features: ______________________________

Quality: 1 2 3 4 5 6 7 8 9 10

Names of persons who use this type map:

	Last	First
1.		
2.		
3.		
4.		

COMMENTS 1. ______________________________

2. ______________________________

Figure 2.--GIS survey form for collecting map information.

EQUIPMENT FORM

COMPUTER? Y / N   Make: ________________   Model: ____________

CONTACT: ______________________ (Last) | ______________________ (First)

What type of tape drive is available for copying data to magnetic tape for transfer? (9 TRACK, 7 TRACK)   TAPE DRIVE: ____________

What density in bits per inch is the tape drive able to write?   TAPE DENSITY : 1. ________ 2. ________ 3. ________

TAPE PROTOCOLS AVAILABLE:

What type protocol translations are available for system compatibility? (ASCII, EBCDIC, BCD)   1. ____________ 2. ____________ 3. ____________

What type tape cassettes are available, if any?   TAPE CASSETTE: ____________

How much on-line storage is available?   DISK MEGABYTES: ____________

What telecommunication capabilities exist at the organization for possible machine to machine connections for data transfer? (SYNC, ASYNC)

COMMUNICATION CAPABILITY: ____________

BAUD RATE: ____________

What file transfer protocols exist at the organization for interactive transfer of data?   COMMUNICATION PROTOCOLS: 1. ____________ 2. ____________ 3. ____________

What type digitizer is used?   DIGITIZER: ____________

What type plotter is used?   PLOTTER: ____________

COMMENTS 1. ______________________________

2. ______________________________

Figure 3.--GIS survey form for equipment inventory.

G I S   S Y S T E M   F O R M

Do you have a GIS system? Y N

If no GIS system exists: Are you considering getting one? Y N
If Yes, approximately when? ______________

What type of GIS system exists at the organization? GIS SYSTEM TYPE: ______________

Is the system your own? Y N

If No, whose system is it? ______________

Are there any telecommunications connections to other systems? Y N

If Yes, to what other system is it connected: ______________

What type of GIS software products are available? (Include Version)

PRODUCT:
1. ______________
2. ______________
3. ______________
4. ______________
5. ______________
6. ______________

Company Name: ______________
Address: ______________
____
______________ City ______ State ______ Zip Code

Company Phone: ____ Area Code | ____ - ______

What type of coordinate system is used for most coverages? Coordinates: ______________

What GIS system to system transformations are used?

System Transformations Available:
1. ______________
2. ______________
3. ______________

Figure 4.--GIS survey form for gathering GIS system data.

What coordinate transformations can be performed?	Coordinate Transformations Available: 1. ________ 2. ________ 3. ________ 4. ________ 5. ________ 6. ________ 7. ________ 8. ________ 9. ________ 10. ________
What projection transformations can be performed?	Projection Transformations Available: 1. ________ 2. ________ 3. ________ 4. ________ 5. ________ 6. ________ 7. ________ 8. ________ 9. ________ 10. ________
Comments	1. ________ 2. ________ 3. ________

Figure 4.--GIS survey form for gathering GIS system data--Continued.

P R O J E C T   F O R M

Project #: ____________

Name of Project: ____

Areal Extent: ____

Tile Composition:

____

____

____

____

Contact: ______________________ | ______________________
Last | First

Comments 1. ____

2. ____

Figure 5.--GIS survey form for assigning project numbers for coverages.

COVERAGE FORM

Project # : ____________

Coverage Name: ______________________________

Coverage Type: Network___ Point___ Vector___ Gridcell___ Line___

Polygon___ Satellite imagery___ Other______________

Coverage Extent: ______________________________

Coverage Features: ______________________________

Coverage Attributes: ______________________________

Date of the coverage: ______________________________

Origin of coverage: ______________________________

How is that coverage related to geographic divisions?

Quad: _______ | _______
Quad-No. | Quad-Dir.

County Code: ________

City: ____________________

State: ____________________

Hydrologic Unit Code (HUC): __________

Other: ____________________

What scale is the coverage? Scale: ______________

Gridsize: ______________

What type of coordinate system did the map use from which the coverage was digitized? Coordinates: ______________

Projection of coverage: ______________________________

Comments 1. ______________________________

2. ______________________________

3. ______________________________

Figure 6.--GIS survey form for coverages or layer information.

LOCATION DATA BASE FORM

Data Base Name: ______________________________

Purpose: 1. ______________________________

2. ______________________________

Located by: 1. ______________________________

2. ______________________________

Data Base Software: ______________________________

Retrieval Capability? Y N

Sort Capability? Y N

Reselect Capability? Y N

Statistical Capability? Y N

Graphics Capability? Y N

What are your data sources? ______________________________

Is the data updated on a regular basis? Y N

Has the data been verified? Y N

What coordinate system is used for the data? ______________________________

What extent is the coverage? ______________________________

How many records are there? ______________________________

Comments 1. ______________________________

2. ______________________________

3. ______________________________

Figure 7.--GIS survey form for identifying location-specific data bases.

UNCOMPUTERIZED FILE FORM

Do you have any geographically related
data that is not in a computer? Y N

Name: ____________________

How is it stored? ____________________

Quantity of data: ____________________

Purpose: 1. ____________________

2. ____________________

How do you get your data? ____________________

Is the data updated regularly? Y N

Has the data been verified? Y N

Comments 1. ____________________

2. ____________________

3. ____________________

Figure 8.--GIS survey form for collecting information about uncomputerized data bases.

POTENTIAL FOR GIS DEVELOPMENT										
Based upon mapping usage:	1	2	3	4	5	6	7	8	9	10
Based upon existing equipment:	1	2	3	4	5	6	7	8	9	10
Based upon existing data bases:	1	2	3	4	5	6	7	8	9	10

Figure 9.--Form used for evaluating potential GIS development.

C O N V E R S I O N   S O F T W A R E

SOFTWARE NAME: ______________________________

COMPANY NAME: ______________________________

ADDRESS: ______________________________

____

______________________ ______ ________
City State Zip Code

SOFTWARE DESCRIPTION:

____

____

____

____

____

____

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____

____

Figure 10.--GIS form for conversion software survey.

APPENDIX B: ACQUISITION OF PAPER MAPS AND DIGITAL DATA

Maps may be purchased from two locations in Tennessee. The State of Tennessee, Department of Conservation, sells USGS maps for Tennessee at 1":24,000"; 1":100,000"; and 1":500,000" scales. They also sell Tennessee geologic maps and maintain an index of Landsat data on microfiche. Maps and information may be obtained from:

James Moore
Tennessee Department of Conservation
Division of Geology
701 Broadway
Nashville, TN 37219
(615) 742-6696

The Tennessee Valley Authority (TVA) serves as a Public Information Office for the National Cartographic Information Center. Maps at 1":24,000"; 1":100,000"; and 1":250,000" scales are available as well as Water Navigation Maps, Recreation Maps, Cadastral Maps, and aerial photographs. Maps and information may be obtained from:

Jack Dodd
Tennessee Valley Authority, Mapping Services Branch
101 Haney
Chattanooga, TN
(615) 751-6277 or (615) 751-MAPS

In addition, the Tennessee Comptroller of the Treasury, Division of Assessment, maintains planimetric maps of the state at 1":50', 1":100', and 1":400' scales. These maps were digitized from aerial photographs made in 1966. The medium is polyester. Property lines for assessment purposes have been recorded on the maps. The property lines have been updated every other year and in some cases more often. Additional information may be obtained from:

Roger Lowe
Tennessee Comptroller of the Treasury
Division of Assessment
Suite 1400
James K. Polk Building
505 Deaderick
Nashville, TN 37219
(615) 741-7628

Information about digital map data from the USGS,NMD may be obtained from:

John Lear
U.S. Geological Survey
National Mapping Division
Eastern Mapping Center
561 National Center
Reston, VA 22092
(703) 648-5577
1-800-USA-MAPS
(703) 860-6045

APPENDIX C: Guidelines for Initiating a GIS

Different agencies have different levels of operation for which a GIS may be used. Needs of an agency are based upon scope of work, urgency of work, purpose of the agency, and even legislative demands. In turn, the fulfillment of needs must be approached based upon the amount of funding available. Three fairy tale characters, Papa Bear, Mama Bear, and Baby Bear, will be used to illustrate the interaction between recognized needs and available funding for the development of a GIS.

Papa Bear is big and has a big budget. Papa Bear might be characterized as follows:

Population supported – 250,000 and up;
Mapping interest – desires to make maps of area of interest from orthographs;
Level of accuracy for maps – 1/30 to 1/50 inch for 1":200' scale;
Establishment of monument control – requires monument control at the first-order level for achieving map accuracy;
Possible available funding – $1,000,000 and up;
Purpose of maps – planning, utility engineering, zoning, property assessment;
Number of offices involved – 5 and up, including utilities.

A typical Papa Bear is a large city with a population of 750,000. A GIS is being developed to consolidate the various mapping efforts. Several agencies including the various utilities will be using the maps. Because of engineering purposes the accuracy must be 1/40 inch for a 1":200' scale. Land elevation contours will also be neccessary. Prior to aerial photography, monument control must be established to insure accuracy. Numerous first order monuments must be established at a cost of $1,300 each over a 325 square mile area. Previously established monuments will also be used, but the accuracy must be verified. The map area must then be flown for orthographs at a scale of 1":100'. The orthographs are then digitized to a scale of 1":200' at 1/40 inch accuracy or 2.5 feet. The total cost of the digital data is 1.2 million dollars for a 325 square mile area. To maintain the accuracy of the map, the orthographs would need to be reflown every five years at a cost of $300,000 to $500,000. Total GIS funding is 4.4 million dollars over a 10 year period.

In the above illustration, several additional comments need to be made. First, please note that this process involves map preparation from scratch. If greater accuracy were desired, for example 1/50 inch for 1":100', the cost would be $5,000 to $10,000 per square mile depending upon the quantity of urban development and the topology of the land surface. Conversely, the less accuracy desired, the less the cost.

Mama Bear is neither big nor small and has a moderate budget. Mama Bear might be characterized as follows:

Population supported – 50,000 to 250,000;
Mapping interest – desires to digitize existing maps;

Level of accuracy for maps – dependent upon accuracy of existing maps, digital data must be within + or -0.005 inch of the stable base map;
Establishment of monument control – no desire, must depend upon controls used by previous map makers;
Possible available funding – 100,000 to 1 million dollars;
Purpose of maps – planning, zoning, property assessment;
Number of offices involved – less than 5.

A typical Mama Bear is a medium size city with a population of 150,000. Only a few agencies will be using the GIS. A utility might use it, but not for engineering purposes so the accuracy is not a major concern. The agency evaluates maps that it has available and decides to use the Tennessee Assessor planimetric maps that were created from aerial photographs taken in 1966. The accuracy is 1/20 inch on each of the scales 1":50', 1":100', and 1":400'. The maps are made of polyester and will not shrink or stretch while being digitized. They already contain up-to-date property lines for the area of interest. The city realizes that many features will need updating because of the age of the maps. The total GIS funding is $500,000 for a 5-year period.

Baby bear is small and has an allowance. Baby Bear might be characterized as follows:

Population supported – 10,000 to 50,000;
Mapping interest – desires to acquire previously digitized data or to digitize areas of interest as necessary;
Level of accuracy for maps – dependent upon accuracy of existing maps, digital data must be within + or -0.005 inch of the stable base map;
Establishment of monument control – no desire, must depend upon controls used by previous map makers;
Possible available funding – less than $100,000;
Purpose of maps – planning, community development;
Number of offices involved – 1 or 2.

Baby Bear is typical of a small city with a population of 15,000. The planning office and the community development office will be using the system so engineering accuracy is not necessary. As much as possible, digital data that already exists from NMD will be used. If other data are needed they will be digitized from existing maps. Each office is interested in the overall development of the area of interest, so accuracy within + or -60 feet at a 1":24000" scale is quite acceptable. Major roads and major distribution lines are sufficient. The total GIS funding is $70,000 for a 3 year period.

Papa Bear, Mama Bear, and Baby Bear are stereotypes of various GIS users. The characterization of each is not necessarily applicable to every user. A small, booming town with a population of 25,000 might decide to use the Papa Bear method to initiate a GIS. In actuality, each might mix and match the methods of developing a GIS. For example, Mama Bear might have a 3-square mile area that is growing rapidly and as a result might want to create a map for that location similar to the way Papa Bear did for the entire area. At the same time, Mama Bear might also want to utilize the USGS 1":24000" Digital Line Graph (DLG) data for resource investigations.

In each case the process for developing a GIS is similar. This process is listed below. Please note that numerous decisions must be made during the process and that each decision limits or expands the options for the next decision.

Papa Bear, Mama Bear, and Baby Bear would first determine if the GIS system would be a single-user system or a multiple-user system (see the flow chart in fig. 11). In most instances, it would be a multiple-user system; therefore, that approach will be followed here.

Each of the three bears would next identify who the system users would be. In the case of Papa Bear, this would be the planning office, the utilities, the zoning office, and the property assessment office. For Mama Bear it would be the planning office, the zoning office, and the property assessment office. For Baby Bear it would be the planning office and the community development office. In each case a study group composed of the system users, consultants, legal representatives, and vendors should be formed. This group would be involved in decision-making and re-evaluation.

Identification of the users sets the stage for determining what the output products will be. Because there are different users at each location with varying needs, each will select the appropriate output products based upon those needs and the availability of funds. The following is a list of typical products (Multi-Purpose Geographic Database Guidelines for Local Governments, Photogrammetric Engineering and Remote Sensing, 1988):

Tax Map	1":200'
Emergency Response Map	1":800'
Zoning Map	1":400'
Land Deveopment Suitability Model	
Appraisal Routing Directory	
Geodetic Control Index	
Demographic Analysis Table	
County Road Map	1":5,000'
Utility / Facility Inventory Map	1":200'
Engineering Map	1":50'
Topography Map	1":100'
USGS 7.5-minute Quadrangle Map	1":2000'

Once the products have been defined, the data items necessary for each product would need to be determined. For example, the following data items would be needed for a typical assessment map (Multi-Purpose Geographic Database Guidelines for Local Governments, Photogrammetric Engineering and Remote Sensing, 1988):

*Parcels	Lot and Block
Parcel Dimensions	*Hydrography
*Parcel Identifiers	*Railroads
Subdivisions	Exempt Properties
Subdivisons Names	Parcel Hooks
*Easements	*State Plane Coordinate Grid and Pulic Land Survey System Grid
Roads/Streets	
Road Names	*Original (Plat) Lines

*Requires decision about positional accuracy at some level

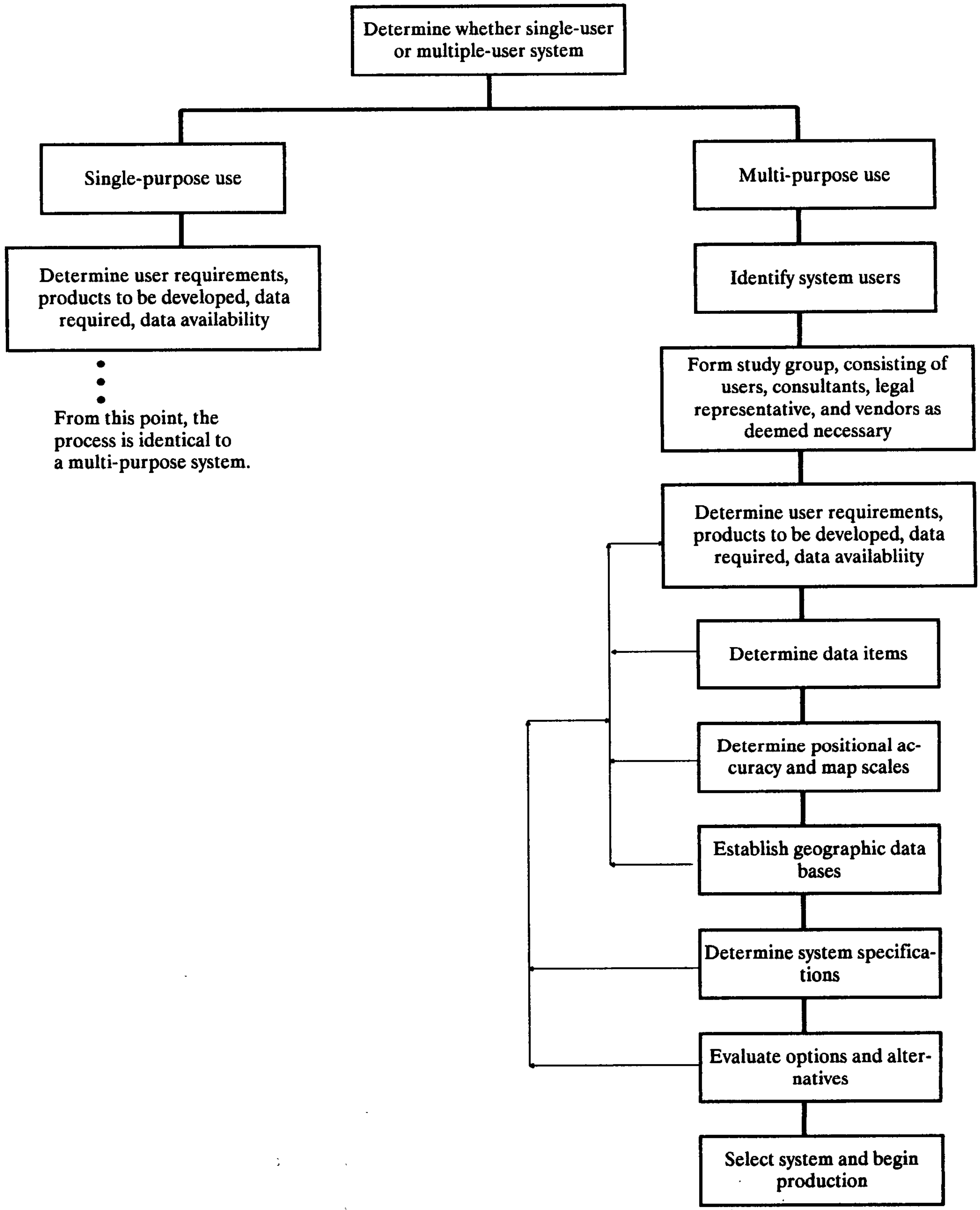

Figure 11.--GIS system design model.

Once the data items are known for each product, decisions need to be made on the degree of positional accuracy and the map scale. For example, Papa Bear might need very close accuracy for his right-of-way lines, 1/50 inch on a 1":200' scale, because the map will be used for engineering purposes by the city transportation department. Mama Bear might need the same accuracy or might need 1/40 inch on a 1":400' scale because her transportation department does little of its own engineering or because the small amount that they do would not cost justify a fine degree of accuracy. Baby Bear will not be using his system with the transportation department so this would not even be a data item. Some standard items requiring decisions are listed below (Multi-Purpose Geographic Database Guidelines for Local Governments, Photogrammetric Engineering and Remote Sensing, 1988):

Administrative Boundaries
Block Lines
Cable Utilities
Control Grid
Culverts
Driveways
Electric Utilities
Fence Lines
Manholes
Parcel Lines
Poles
Railroads
Right-of-way Lines
Sidewalks
Street Centerlines
Swimming Pools
Topography (Contours)
Zoning Lines

Building Footprints
Bridges
Control-first, second, third order benchmarks
Docks
Easements
Edge of Pavement Line
Gas Utilities
Parcel Centroids
Physical Geography (Soil, Geology, Hydrography)
Ridge Lines
Sewer Utilities
Spot Elevations
Subdivision Lines
Telephone Utilities
Water Utilities

Once positional accuracy has been determined the data content of the geographic database should be designed. A typical data base should include (1) control - reference framework, (2) street network - centerline, (3) hydrography, (4) parcel/parcel identifier, (5) planimetry, and 6) topography (Multi-Purpose Geographic Database Guidelines for Local Governments, Photogrammetric Engineering and Remote Sensing, 1988).

At this point Papa Bear, Mama Bear, and Baby Bear must evaluate how much they can spend to meet their needs. This directly relates to the user needs, the products each user desires, and the positional accuracies selected for the various products.

Next, system specifications need to be developed based upon the data requirements, data resources, geographic reference scheme, and the system products. Basic system capabilities (Tomlinson, 1981) include the following:

1. Digitization – Insure that software, hardware, and digitizer are all compatible. Insure that the accuracy of the digitizer is within a + or -0.005 inch.
2. Edgematching – The ability to join two maps together to form a larger map.

3. Report generation and editing of lines
4. Polygonization – The ability to create areas that can have data associations.
5. Labeling
6. Plotting – Insure software, hardware, and plotter compatibility.
7. Data storage – Allow sufficient storage for data and software. Insure that hardware will allow for expansion of data storage.
8. Data management - The ability to add, update, delete, sort, and select subsets of data.
9. Browsing and plotting a derived map
10. Updating

Typical map handling capabilities (Tomlinson, 1981) are

1. Data manipulation
    - Reclassify - attributes
    - Generalization
        - Dissolving and merging
        - Line smoothing
        - Complex generalization
    - Interpolation
        - Centroid allocation
        - Contouring
    - Scale change
    - Distortion elimination - linear (rubber sheeting)
    - Projection change

2. Generation
    - Points
    - Lines
    - Polygons
        - Simple five-sided polygons
        - Irregular polygons with islands
        - Circles
        - Grid cell nets
        - Latitude and longitude lattices
        - Corridors

3. Data extraction
    - Search and identification
        - Attributes
        - Shapes
    - Measurement
        - Number of items
        - Distances (straight line between points, along convoluted lines)
        - Size of areas
        - Angle direction
        - Volume (cubic measure)

4. Comparison
    - Intersection - overlay
        - Point-in-polygon
        - Polygon-on-polygon (grid cell on polygon, circle on polygon)
    - Juxtaposition (proximity)
        - Shortest route
        - Nearest neighbor
        - Line of sight
    - Contiguity
    - Connectivity
    - Complex space-attribute-time correlation, rate of change

5. Interpretation
    - Determination of optimum location
    - Determination of suitability
    - Determination of desirability

After evaluating the various vendor products, a re-evaluation process should begin within the study group to determine options and alternatives. Once this has been accomplished, the system can to be selected and full speed GIS work can begin.

A warning is in order at this point. The above is a model for initiating a GIS. As such, one should feel free to modify it, add to it, or delete from it. Many different paths can lead to the same result. In reality, very few GIS efforts evolve in a nice orderly fashion as described above.

Numerous non-graphics tasks can be worked on prior to having software or hardware. Many tasks such as education, the starting of a user newsletter, conference attendance, meetings of encounter groups, committee planning, consortiums for financing, data base development, and verification of existing data can all be worked on simultaneously.

A GIS does not necessarily have to start with a wide range of users and several applications. One single, high priority application can be the foundation for GIS development. For example, a GIS could be used to resolve a transportation problem or for complaint administration or to keep track of building permits. Once started, other offices can then be brought into the GIS arena.

Each GIS is similar and each is very different. Success is measured in terms of how satisfied the user is with the product being created. If the system provides information in the form and quality required and at acceptable cost, then the system is a success.

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