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I am submitting herewith a dissertation written by Milton Allen entitled "An Evaluation of Computerized Systems for Acceleration of Interpretations from Soil Surveys and Other Resource Information." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Plant and Soil Science.

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4

AN EVALUATION OF COMPUTERIZED SYSTEMS FOR ACCELERATION
OF INTERPRETATIONS FROM SOIL SURVEYS AND
OTHER RESOURCE INFORMATION

A Dissertation
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Doctor of Philosophy
Degree
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ABSTRACT

Basically, two questions prompted this study: (1) is a digital soils data base needed? and, if so, (2) which system or systems can handle and present soils information most efficiently and effectively?

Objectives were: (1) to identify needs and problems of a digital soils data base, (2) to evaluate many systems for handling soils information, and (3) to choose systems and use them to demonstrate the capabilities of computer-assisted spatial analysis and mapping systems in handling soil information.

Computerized soil surveys and digital soils data bases are needed because soils information is used in the planning process for nearly all types of development. Since original soil surveys may be complex, simplified presentation should be directed to each of many users.

The needs and problems surrounding the development and use of a digital soils data base were assembled. On 55 systems out of more than a hundred systems as much information as possible was assembled from published literature, company brochures, and response to questionnaires. Questionnaires were returned from 50 Soil Conservation Service (SCS) state offices, 30 Land Grant Universities, and 4 SCS Technical Service Centers.

To demonstrate how data are stored, manipulated, and retrieved from a computer-assisted system, the two systems chosen for further

consideration and extensive testing were the Map Information Assembly and Display System (MIADS) and the Information Manipulation System for Grid Cell Data Structure (IMGRID). MIADS was used by the SCS state office in Nashville, Tennessee, and TVA's Natural Resource Service at Norris, Tennessee, had IMGRID. MIADS had interactive editing capabilities; IMGRID did not.

The two systems were tested on a five minute (approximately 6900 hectares) portion of the Concord Quadrangle covering parts of Loudon, Knox, and Blount counties in Tennessee. These computer-assisted systems were used to join soil survey information from three counties into one project area. Grid cells of 1.08 hectares (2.68 acres) were used for both systems. Most of the encoded data were taken from soil surveys. However, land use was determined partly in the field and partly from interpretations of 1975 aerial photographs and a 1968 revised topographic map. The capabilities of MIADS and IMGRID were demonstrated by using encoded soils data along with other information from topographic maps. Interpretive and single factor maps such as suitability for farmland, depth to bedrock, land capability class, and slope were produced to show how detailed soils information can be simplified for a particular user.

Both MIADS and IMGRID were used for combining land use with soil interpretations to show how different kinds of farmland are used. IMGRID was used to combine proximity to roads, streams, and residential development with interpretations from soils to show suitable landfill sites. Potential landfill sites not conflicting

with development were also displayed with IMGRID, but this could not be done with MIADS.

Patterns on IMGRID maps are easier to see than those on MIADS line printer maps because of the overprinting capabilities of IMGRID. However, IMGRID patterns become more difficult to see as the number of classes increases. Maps with 3 to 5 classes are much easier to comprehend than those with 10 or more classes.

Of the two systems selected to demonstrate the capabilities of computerized systems, IMGRID was capable of performing more analyses than MIADS. Thus more kinds of information could be handled and presented using IMGRID. However, because of the greater volume of data processed by IMGRID the total cost of encoding, keypunching, and other operations was greater than for MIADS. Direct comparison of costs for the same operation could not be made because the way of charging for processing differed between the SCS computing center in Nashville and the TVA computing center in Norris.

Evaluation of the maps and supporting materials produced by the two systems leads to the conclusion that IMGRID is definitely a more effective system for processing resource information. Further investigation of costs would be needed to determine how much is saved by MIADS.

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CHAPTER I

INTRODUCTION

The purpose of this study was to explore computerization of soil surveys and to investigate which system or systems could be used to produce interpretive maps for use in planning.

Special objectives were: to identify the needs and problems surrounding the development and use of a digital soils data base; to identify and evaluate many different computer assisted spatial analysis and mapping systems in relation to the use of soils information in preparation of interpretive maps, performance of analyses, and management of data; to test the ability of each system to join soils information from two or more surveys and combine it with other resource information; to show how data are input, manipulated, and retrieved from each system; to test two systems and use them to demonstrate the capabilities of computer assisted spatial analysis and mapping systems to handle soils information.

To accomplish these objectives and to select two systems to demonstrate computer capabilities, many systems had to be identified. Information was obtained on more than 100 systems from the literature, conversations with vendor representatives and users of some systems, and from answers and literature received in response to a questionnaire prepared by the researcher and sent out to the Soil Conservation Service (SCS) state offices and technical service centers and to major

Land Grant universities. From this information more than 50 systems were compared to determine if any of these systems would be suitable for the final comparison. Several of these systems were capable of doing the job, but all of them could not be selected.

After evaluating the 55 systems, the two selected to demonstrate the capabilities of computers were the Map Information Assembly and Display System (MIADS) and the Information Manipulation System for Grid Cell Data Structures (IMGRID). MIADS was used by the SCS in the Nashville state office. The Tennessee Valley Authority (TVA) Natural Resource Services, Land and Forest Resource Division in Norris, Tennessee, used IMGRID. The study area selected was a five-minute portion of the Concord 7-1/2 minute Quadrangle in East Tennessee. Soils information, land use, and selected roads and streams were obtained from existing documents such as published soil surveys, a topographic map, and aerial photographs, along with some field checking. The data were encoded, corrected, rated or grouped by single factor or interpretation, analyzed, and combined with other data in various ways. For example, soil mapping units were rated for prime farmland and other interpretations and factors. These interpretations and factors were printed as line printer maps and combined with land use and other information to make composite maps that may show conflicting or nonconflicting uses. Maps produced by both systems were evaluated and compared to determine their usefulness for resource planning.

CHAPTER II

REVIEW OF LITERATURE

A. Policies and Potential Solutions

Consideration of national and state soil conservation and land use legislation has accelerated the demand for soil data that can be analyzed or combined with other variables. Planners and soil scientists have combined efforts to develop interpretive maps that can be used for environmental land planning. Interdisciplinary teams are working toward integration and development of combined problem-solving abilities to fully utilize the potential of the data (Meyers et al., 1974).

To obtain the necessary data to comply with new regulations and policies, new and better ways of handling information must be developed. Soil data can be readily accessible to allow for soil interpretations to meet user needs if it is digitized and stored in computers. Soil interpretations now made by using manual techniques are time consuming and expensive (Nelson and Johnson, 1976).

Soil data can be easily examined, studied, and compared with other resource data when the computer is used to store, sort, and recall the data. No more than two or three map overlays can be considered at the same time when manual studies are performed on map data. The computer can compare soils with an almost infinite number of other types of data. Any data that can be displayed on a map can be put into

a computer system (Tennessee State Planning Office, Natural Resource Section, 1975).

B. Data Acquisition and Communication

The data that are of most concern to land planners are soils, land use, transportation, and environmental information. Whenever possible this information should be obtained from existing documents such as published soil surveys, topographic maps, and other sources.

Faster methods for acquiring new data and better ways of communicating existing information are needed if better decisions are to be made in a reasonable amount of time. The current method of surveying soils is too slow and expensive and may not fulfill the data needs in the required time period (Myers et al., 1974). Remote sensing techniques were used to collect soil data in South Dakota because they were available and could be used almost immediately. However, in some regions, remote sensing techniques may not be available for general soil information. Therefore, other methods may have to be applied. The Tennessee Valley Authority (TVA), at Norris, Tennessee, for example, has been utilizing experts in various fields to produce "landtype" maps (Fink and Elder, 1982). These maps are produced by teams consisting of soil scientists, geologists, and biologists. They can be interpreted for some of the same purposes as the published soil survey. However, although the resulting map is more generalized it can be developed in a few weeks or months, while detailed soil surveys usually take longer. The term landtype map was used in Bailey's

hierarchy for ecosystems (Bailey, 1976). He defined nine levels in his classification scheme. The amount of detail increases in ascending order as levels increase. The maps produced at TVA correspond to level seven of Bailey's classification scheme.

Another factor to consider is how to communicate the complex soil survey information to the public. Fenton (1975) said that agricultural land values differ for several reasons and soil survey information is a valuable tool for evaluations and tax purposes. Many other interpretations can be made from this information. Jansen and Fenton (1978) found communicating soil survey information to the public more difficult than other maps because soil survey information is complex and the needs of land users and planners are varied. Use of the comprehensive soil maps may be difficult for people interested in only one or two characteristics for a specific interpretation. Because an efficient way is needed to sort out soil information, computers are increasingly used to store and process this information.

C. Generalized Information

General soil maps are needed because of the limited number of facts that the human mind can comprehend simultaneously. General soil maps are made for large areas ranging from about 250,000 sq km to 250 sq km and it is suggested that no more than 18 soil associations be in the legend (Simonson, 1971). These maps may not be justified by what is shown on them but in what can be grasped and understood. General soil maps show landscape characteristics and provide soil behavior

predictions that are adequate to formulate a plan (Bartelli, 1966). On the other hand, a detailed soil map is necessary for application of the plan.

Webster and Burrough (1972b) said that soil maps may be produced by delineating areas for different management as part of the process for land use planning. They indicate that the larger the area of soil with the same management capability, the more freedom a planner has to design a site for a particular use. But, at the same time less information is contained in each area. General soil mapping is normally done by experienced surveyors applying their skill to judge and classify soil (Webster and Burrough, 1972a). The computer can help to simplify complex and detailed information. Also, data can be handled quickly to produce maps of different kinds. It is the need for several kinds of interpretations that makes computers a necessity for simplification of soils information for resource planners.

Nichols and Bartelli (1974) found computer-generated maps to be useful, especially for general planning. They indicated that the Soil Survey Manual emphasizes the need to organize soil maps to present information for the universe under consideration. Computer-generated maps allow design of maps to fit specific needs for the user.

Computers can be used to generate interpretive maps by selecting the dominant soil within a grid cell by estimation from the detailed soil map (Nichols, 1975). By rating the dominant soil in each unit or grid cell the user can then generate interpretive maps as a graphic

display on unlined paper. The user has the benefit of detailed soils information on which to base each decision because the original data remains in the system and is available for many different interpretations.

D. Geographic Information Systems

Several feasible schemes have been developed for storing the many types of geographic information (Thorpe, 1977). She recognized that not all schemes or data structures are good for storing all types of data, so one approach may be to choose simple, general schemes well suited to the types of data that land use planners and researchers use most. Hill et al. (1974) found that computer systems developed without sufficient preliminary design and field involvement may be unnecessarily limited in scope and lacking in proper user documentation.

The major differences in geographic information systems are confined to the manner of storage, processing, and output of data. Data are stored in the form of grid cells, polygons, lines, and points. The two most widely used methods of storing data are grid cells and polygons (USDA Forest Service, 1976). The general characteristics of these two methods are described in Table 1.

Software packages (computer programs) have been developed by universities, government agencies and private firms. The major purpose of such systems and packages is to serve the particular needs of the agencies and to solve their specific problems (Brassel, 1976). A large number of comprehensive mapping systems, geographic information

Table 1. General characteristics of grid cell and polygon methods of storing spatial data in digitized form.

Grid cells

1. Maps are subdivided into small cells identified by one or two characters.
2. Printer characters are codes which define characters on a line printer.
3. Boundaries between separate areas are implicit through changes in codes but not explicitly drawn.
4. Smallest delineable area is the unit cell.
5. Extraction is by cell code only.
6. Area statistics represent global counts of all cells.
7. Overlaying can be performed routinely only for map layers of the same scale.
8. Hardware requirement limited (computer, keypunch, cardreader, and printer).
9. Not difficult to learn.
10. Use of the system is relatively inexpensive.

Polygons

1. Maps are divided into polygons according to selected attributes.
 2. Polygon boundaries can be delineated with as much fidelity as necessary.
 3. Polygons can be extracted by number, characteristics, or selected area.
 4. Systems vary considerably in the map processing options offered.
 5. Hardware requirements include a computer, line printer, digitizer and plotter.
 6. Operation of the polygon plotting systems requires a substantial amount of training and technical support.
 7. Use of the system is fairly expensive.
-

Source: Adapted from the U.S. Forest Service, 1976.

systems, and data manipulation software have been developed in this environment.

1. MIADS

One software package evaluated in this study is the Map Information Assembly and Display System (MIADS). Amidon (1964) stated that maps contain information that is basic to land management planning. MIADS can be used to transform conventional map symbols into two character codes which are punched into cards. A land manager can then assemble and display these codes by computer for a specific job. Amidon (1966) said that a computer-oriented system could be used to record, update, assemble, and display map information quickly and efficiently.

The MIADS system is made up of a set of four relatively simple computer programs and one International Business Machine (IBM) package program. Each program performs certain fundamental operations that are involved in manipulation and processing of point-area mapping systems. Although the system lacks sophistication in terms of what is possible at the state-of-the-art level of automatic data processing, the operations that are available may be combined in diverse orders and sequences to provide a powerful, flexible, and economical tool for processing planimetric maps (USDA Soil Conservation Service, 1972).¹ MIADS can: create and maintain a master file of coded data

¹USDA Soil Conservation Service. 1972. MIADS/360 unpublished paper.

for a series of maps for any project area; translate or convert sets of codes from one or two base maps to a new set of codes on a new map; combine and merge original or translated codes from two maps to derive a new map; and, perform frequency counts and expansions for the various codes to comprise a map and summarize the contents of a map, and graphically display the maps on a printer if desired.

Dissmeyer (1975)² used MIADS for stratifying watersheds by soils and other factors that have an effect upon the management of a watershed. MIADS produces a category map and tables containing the area of each strata and the total area of the watershed. This system converts conventional map data into a two-character code system capable of describing approximately 2,200 different strata.

2. IMGRID and Modeling

Physical land variables may impose limitations on the potential of land for a variety of human uses. These limitations can be determined by a capability analysis of the land which is a systematic and quantitative evaluation according to Chiesa et al. (1975). This type of analysis is most useful early in the planning process, e.g., examining potential sites for a proposed project. The physical variables considered in a capability analysis can be combined with social variables to produce a suitability analysis which can be used as a basis for regional planning.

²Dissmeyer, G. E. Unpublished paper. 1975. MIADS—a new tool in water resource management. Hydrologist, Division of Flood Prevention and River Basin Program state and private industry. U.S. Forest Service, Atlanta, Georgia.

The Information Manipulation System for Grid Cell Data Structures (IMGRID) is a package of computer programs designed for the manipulation of natural resource and land planning data which is qualitative in its thematic content and varies over geographic space (Sinton, 1976). The specific manipulative capabilities of IMGRID are designed to help land-use planners and designers analyze the natural and man-made characteristics of an area or region. The IMGRID system uses a series of keywords to perform various mapping, analysis, and modeling techniques. It can perform all of the functions that were outlined in the MIADS system, except IMGRID uses overprinting to produce gray level maps and is limited to mapping 20 levels per run. The original IMGRID was written by Sinton at Harvard University to be used as a teaching tool, but version 2.5 has keywords by Vesper and Kilpack of the Holcomb Research Institute, Butler University, and by Holmes of TVA in Norris, Tennessee, where it is installed. Version 2.5 of IMGRID was used to do the analyses and produce the IMGRID maps shown in this study.

E. Map Referencing Systems

Beavers (1978) stated that a spatial reference system provides the framework for expressing and representing attributes of land characteristics in a computer-assisted land information system. A spatial reference system provides this framework in a systematic partition of continuous sets of points. These sets of points represent the earth or a portion of the earth. Spatial reference systems are developed by one basic process with several variations

based on coordinate organization, on measurement base, and on origin definition. The process is easily outlined for developing a spatial reference system. Sinatra et al. (1973) stated that the computer must be able to identify every location on the surface of the map which it prepares. An X-Y grid coordinate system allows the computer to identify, locate, and separate any one point from all other points on the map.

Berry and Marble (1968) said that "spatial data varies from place to place and from time to time." Geographic data stored in association with some defined area, can generally be converted easily to another type of data structure so that data from projects not designed for that system can be processed (Thorpe, 1977).

A large amount of information is needed for regional modeling as related to simulating the behavior of human ecosystems, and there must be some way of referencing this information to points on the ground and locations of specific points on maps and photographs. Tucker (1971)³ evaluated several proposed reference systems and concluded that for automatic data processing the geographic (or geodetic) reference system of latitude and longitude is far preferable to any other system. Such a system was selected by Fenton (1975) for use in Iowa because of its prevalence and the ease of referencing field data and previously existing data. After evaluating several

³Tucker, T. C. 1971. Some considerations on a reference system for geographical location in a computer-based regional modeling data bank (unpublished memo). Oak Ridge National Laboratory, ORNL-NSF Environmental Program, Oak Ridge, Tennessee.

referencing systems McCroskey (1975) concluded that the geodetic system of latitude and longitude was the best reference system to use for large regions.

CHAPTER III

DIGITAL REPRESENTATION OF SOILS INFORMATION

A. Information Content of Soil Surveys

The soil survey is a major source of information about landscape characteristics now being used for regional planning. The first approximation of regional plans may be based on generalized information about landscapes. Since general soil maps are developed through orderly abstraction from original field surveys, they provide behavior predictions and reveal landscape characteristics that are adequate for formulation of a general plan (Bartelli, 1966).

Good inventory procedures are needed to make full use of soil survey information because it is presented on a wide range of map scales. For example, detailed soil maps show mapping units in sufficient detail to be significant to decision makers at all levels. Interpretations based on such information aid in the improvement of detailed plans. Combination of these small units may be used also for maps at intermediate levels of generalization.

Parker (1973) suggested that the complexity of soil survey information is one reason why computerization of the data is needed to simplify it for various users. Jansen and Fenton (1978) found soil survey information to be difficult to communicate to the public because soils data are relatively complex and there is a diversity of information needs among land users and planners. Therefore, an

efficient way is needed to sort out information required by a specific user group. The use of computers is a logical solution for storing and processing soil information.

Computers are used to store, manipulate, and retrieve large amounts of soils and other natural resource data. The main use has been computer generation of interpretive maps. Interpretive maps, as referred to in this study, are generalized from detailed soil maps either by manual or computer-aided techniques. Two basic types of interpretive maps are produced: single purpose and single factor maps. Single purpose maps, such as suitability for septic tanks, are made after a qualified person, usually a soil scientist, has rated the soil mapping units for certain uses such as suitability for farmland, suitability for septic tanks, or suitability for sanitary landfill development. Single factor maps, such as slopes, are made by abstracting data such as slope or depth to bedrock from the mapping unit descriptions. The major concern of this study is the use of computers to simplify existing soil surveys to make them useful to a variety of land users and planners. Bie (1980) noted that computers have won acceptance also as support for traditional soil map making and as a component in the development of quantitative methodology for soil survey.

Some characteristics of soils data pose many problems that may not be associated with other data. Problems involved in utilizing the current cooperative soil survey as a tool in regional environmental analysis and some solutions devised to accomplish this task will be discussed in this chapter.

Some of the problems encountered when computerizing soils information are due to the different ways in which soil surveys are published, inclusion of features other than soil map units, and different scales of the source maps. Published soil surveys and manuscripts have many sizes, shapes, colors, and materials. For example, if the encoding process is done by placing a grid over the photobase soil map, symbols in wooded areas may be hard to read, or the grid may not fit precisely because of instability of the material that the map was printed on. Also, some of the older soil surveys were printed on distorted photobase maps. Since information from such old soil surveys is still useful, better ways must be developed to use it. In order to combine soils data from these surveys with other resource data, some type of ground reference system is necessary. Combination of data from distorted photobase maps with data from a base that is planimetrically correct is difficult. For example, combination of land use data recorded on the U.S.G.S. topographic map with soil data recorded on a distorted photobase map may cause problems. Of course, the soil surveys that are published today have less planimetric distortion than some of the older surveys.

A detailed soil survey includes in its legend all mapping units in the survey and presents them by three grades of alphabetical ordering. The Soil Survey Manual lists three kinds of surveys: the detailed, reconnaissance, and detailed reconnaissance as original maps (Soil Survey Staff, 1951). The National Cooperative Soil Survey

now recognizes five orders of surveys ranging in detail and scale from high to low intensity. Each of these surveys has its own legend and degree of intensity. With manual techniques it is difficult to use these surveys interchangeably for planning.

B. Reasons for Digitizing Soil Data

Interpretations and planning for various uses of soils can be aided by either manual or computer-aided techniques of handling soils information. Both are similar in structure and sequence in that the data have to be acquired, organized, encoded, manipulated, analyzed, and finally put in a form for use by decision makers.

For many one-time projects, manual processes usually are more economical in terms of personnel and time. However, if data are to be used for more than one project, computer-aided techniques may be more practical. Decisions as to the better technique should consider the analyses required, the analyses that could be undertaken, the amount of data that must be handled, how often it must be handled, and how quickly results must be attained. One is likely to select a computer-aided system when there is a large volume of data, the data are used frequently, or the problems have a certain degree of similarity. For example, if it is probable that the land use and soils data will not be used together to answer questions, then the manual approach may be the best choice. However, if in the future, it is much more likely that other questions will be asked about urban development on soils capable of supporting agriculture, the

long-range cost effective method would probably be the computer-aided system, even though the initial costs may be higher (Calkins and Tomlinson, 1977).

When selecting a computerized system for soil information one should consider the cost of printing the interpretations needed, and the desire for combinations with other data. In a well designed system, visual displays of soil interpretations can be done versatily and efficiently, once a digital file has been created. Maps can be printed as needed to meet user demands. The maps may be inexpensive, costing as little as \$6.00 a copy, according to Nichols and Bartelli (1974).

A good system will allow one to select and portray soil information of interest to a particular group of users and to omit all other facts and details (Jansen and Fenton, 1978). Summaries and maps can be printed to show only the particular types of soil information and detail necessary for a given purpose.

One advantage of the computer-generated map is that the detailed soil mapping units are retained in the system for greater precision in interpretation (Nichols, 1975). The detailed soil map may have between 50 to 100 mapping units that can be computer translated to three to five classes of limitation, suitability, or potential for each use. Nichols (1975) points out that a map with only three to five kinds of divisions or units can be easily understood. Computer-generated maps have the advantage that any one of a number of single interpretations can be produced from the 50 to 100 detailed mapping units.

Maps reflecting the soils potential for major land uses are basic tools of planners. Such maps can be made from stored data by merging original or translated codes. Other soil-related characteristics important to planning can be displayed by single-factor interpretive maps. Data such as roads, boundaries, streams, and cultural features are also of importance, and can be integrated with digital soils data.

C. Input of Map Data in Digital Form

A digital data base may consist of cells, polygons, lines, or points. The size and shape of map units are particularly important in a cell base system, because these components will determine if a map unit is captured in the encoding process when large cells are used. For example, if soils suitable for growing a particular high value crop are in narrow units along streams, most of them would not be encoded if large cells were used. This is just one reason why size and shape of map units are so important when determining the cell size to be used. McCroskey (1975) studied cell sizes as related to data capture and cost, and found that 1.08 hectare cells (2.68 acre) were sufficient for capturing soils data efficiently. The amount of extra time and cost incurred by using even smaller cell sizes could not be justified by the amount of soil data gained. Of course, the smaller the cell size, the more data will be captured accurately, but using present technology, additional accuracy may become economically unsound below a cell size of about one hectare.

Soil surveys are generalized to some extent when one hectare cells are encoded because long and narrow soil mapping units may not be captured in the encoding process. The smaller the cell size, the more detail the system will capture, but likewise, the more information the computer has to handle. For example, if 1-acre cells were used instead of 1.08 hectare cells (2.68 acres) the computer would have to handle 2.68 times as much data.

The soil map contains much information in the form of symbols indicating gravel pits, wetness, areas of rock outcrop, and erosion. The symbols are informative to the map user, but may be hard to digitize, especially if automatic scanners or digitizers are used. Also, delineations on a soil map form many different patterns, including those which are commonly called "donuts." When one soil map unit completely surrounds another, both the inner and outer unit make up the donut. These donuts present a problem for some polygon systems, because in simple polygon systems the area of the inner unit may be summed twice, once as part of the outer unit and again as itself. To solve the problem of summing the inner area twice in a polygon system a line can be drawn from the outer edge of the inner unit to the outer edge of the outer unit. This will give the computer a starting and stopping place when summing area. Donuts do not present a problem for grid cell systems, because the area of each cell is summed independently of others.

"Soil map scales vary from several hundred miles to the inch to about 1 mile equals 12 inches" (Nichols and Bartelli, 1974). The

scale problem may be handled in several ways in a grid cell system. One is to choose a grid that has the same scale as the source document and encode the data in a fixed matrix that would allow coverage of the area at any scale. Another is to redraw data boundaries to a common scale base map.

Problems such as soil names changing from one county to the next are generally solved by producing and joining interpretive maps, rather than the original soil maps. Even though similar soils may have different names across county lines, interpretations are usually the same. Another way to handle the soil name problem is to have a qualified soil scientist give similar soils the same name in all counties of the project area.

Methods of input vary, depending on the system used. Grid cells can be used to sample soils data for input in various ways. Two frequently used methods of grid cell coding are the center dot method, and predominant type coding. The center dot method uses a grid that is generated with a dot in the center of the cell. This grid is overlain on the source document, and the units that lie below each dot are coded. Predominant type coding consists of assigning each grid cell the value that makes up most of the cell. With both of the methods, data are lost in proportion to the size of the cell used.

Another way that grid cells may be used is to create a polygon by placing a grid over the source material, and drawing a series of horizontal and vertical lines to form the polygon. This

system was demonstrated by the author at the Oak Ridge National Laboratory in a cooperative effort with the Soil Conservation Service to encode soil survey information. The polygons produced in this manner are only estimates of the true polygon because portions of the adjacent polygons are cut off or included in the new polygon. Other systems use a series of points connected by lines, and the more points used, the closer the representation of the true polygon.

Another way of putting data into computer systems is by polygons or lines. One problem shared by some polygon systems is that the lines between adjacent polygons are traced twice, and often a double trace can be seen on the output if the lines are not traced exactly both times. However, by using line segments and tracing only the lines that do not share common borders with the adjacent polygon and connecting them at points called nodes, this double trace can be eliminated. Peucker and Chrisman (1975) used the term "neighborhood function" to describe input with line segments where both sides of the line are identified. With soils data, this has an advantage over a grid cell or polygon system because, in many cases, the adjacent soils help determine how a site is to be used. Polygon systems which do not show what is in the adjacent polygon are seriously handicapped in use for soils data. Grid cells are useful for production of interpretive maps which show whether like cells occur in a cluster large enough to support a specific land use. However, some grid cell systems produce maps that are hard to read when all symbols in the legend are printed.

The methods discussed so far have dealt with manual coding techniques except for double tracing of lines between polygons, which is manual coding in the sense that an operator moves a cursor over a digitizer. Other problems are identified with use of automatic scanners. The procedures are elaborate and impressive, but sometimes a great deal of preparation has to be done before these scanning devices can be used. For example, a published soil survey has many lines that have nothing to do with soil boundaries. Before the scanning device can work properly, a source document with only the soil boundaries must be secured. The different separations used in the printing of the survey may serve this function; otherwise, one must manually draw only the soil boundaries from the published survey. The Advance Mapping System (AMS) that was developed by the SCS uses a scanner to encode soils data (Johnson, 1979).

Another factor to consider when map data are input in digital form is resolution. Resolution as related to this study means how fine or accurate a line is drawn between two polygons or how closely a stream or road can be represented. The resolution of the system depends largely on the method of input, output, and the capabilities of the equipment used to accomplish these steps. For example, in cellular systems the resolution is dependent on the cell size used. With polygon and line systems, the devices used to handle the data are capable of producing products with greater resolution than is needed for most jobs. Therefore, resolution for polygon systems is not generally dependent on the equipment but on the time and expense the user is willing to bear in order to gain the desired resolution.

D. Graphic Display Hardware

A great variety of hardware devices can be used to display the products from any soils-based information system. The choice of devices is a matter of purpose and cost. Because money is usually a limiting factor, decisions may be made which limit the display capability of the system.

There are many options among graphic display devices. Some are:

- Hardcopy vs. CRT display (cathode ray tube)

- Color vs. monochromatic output

- Cell display (raster) vs. vector display

- Single line width vs. multiple line weights

- Size of output (physical dimensions)

- Resolution of the display

- Medium of output (vellum, film, printer-paper)

Basically, there are three options. The earlier systems used the alphanumeric line-printer to give graphic displays by overprinting characters to give shades. The standard line-printer types 10 characters per inch across the page and 8 characters per inch down the page. Line-printer output is inexpensive, in part because most operations already have a line-printer, so no additional hardware is needed. One disadvantage of line-printer output is that each individual character is evident and the output can be identified as coming from the computer. The IMGRID and MIADS systems are based on line-printer output.

The second option in display devices is the cathode ray tube (CRT). These devices are available in a wide range of resolutions and color capabilities. The thing they all have in common is that the displays are ephemeral—they do not produce a hardcopy. CRT's are best for interacting with the system for analysis or editing, because the results of changes can be seen immediately.

The third option is the plotter—a device designed to produce a hardcopy graphics image. Some vector plotters can draw smooth lines in a variety of widths on any kind of media in sizes of 0.9 meters (3 ft) by 1.8 meters (6 ft) or larger. Such plotters can be purchased to plot within 0.127 to 0.025 millimeters (0.005 or 0.001 inches) or finer. Electrostatic plotters draw fine lines by printing a matrix of dots from 40 to as much as 160 per centimeter (100 to 400 per inch). Plots from such devices closely resemble plots drawn with a pen on paper. Devices are also available to produce color plots on either paper or film. The output from many plotters cannot be distinguished from the best work of a draftsman.

Because there are so many options available, a system can be configured to meet any need. Generally, budgets will be the limiting factor so that compromises will have to be made in setting up a system. For this reason, the purpose or purposes of the system should be thought through before any hardware is purchased.

E. Data Base Management

For ease of system use, there must be programs or routines that permit the creation and use of data bases. To be a useful

system there must exist the ability to add new data, delete existing data, change or modify existing data, add files, and delete files. The system should have routines that would allow the user to combine different kinds of data to create a new file. For example, it should be able to combine soils information with land use and other data.

Another important feature of data base management is the capability to update and edit data. In some computer systems, updating or editing of data requires replacement of the entire file, thus making the procedures lengthy and expensive. However, such procedures can be shortened if interactive editing capabilities are available. For example, MIADS and IMGRID were in the SCS office in Nashville and at TVA Norris, respectively. MIADS had interactive capabilities and IMGRID did not. The systems were set up this way by choice of the two computer centers. When using MIADS, changes were quick and results could be seen within seconds. However, when using the IMGRID system with cards, changes could not be seen until a new job was printed and that might require between 2 hours and 3 days.

Perhaps the most important consideration in automated data processing is to be sure that the data are free of errors. That even small errors in a data file may cause serious trouble when combined with other data, is just one reason why editing of a data file is so important. Changes in an area should be added to a data file to keep

information current. This is especially true for information like land use that is constantly changing.

Updating of information is necessary as conditions change. For example, if landfill interpretations from soil surveys are to be combined with residential development from the land use map, the land use map should be updated to include all new subdivisions, towns, and roadside residences. By updating residential developments and other land uses as they change, costly errors in planning may be avoided. New subdivisions spring up every day and systems with easy update capabilities can handle new additions and updates with ease.

Calkins and Tomlinson (1977) said that the management function is probably the most deficient area of information systems developed for land use planners. One reason is that most of these systems are developed to help solve the problems of one discrete project. Therefore, they are usually rather limited in scope and their inadequacies surface only in the time of crisis. The required features can usually be designed into the information system at the beginning if thought is given to long-term objectives. To inject these features on a crisis-by-crisis basis is more expensive in the long run. The amount of required time and personnel is greater if an information system is not adequate.

F. Data Analysis and Display

To be viable, a system should be able to perform analysis functions and combine soils data with other resource data. Some

decisions require information about soil, water, political considerations, ownership, and various other kinds of information for site planning. These are but a few of the reasons why a geographic information system should be able to perform some functions such as overlay, window, search, weight, scale, recode, and merge.

1. Overlay

Overlay compares two maps and selects areas that represent the intersection of polygons or cells according to specified criteria. For example, if one map represents soil phase and a second map represents land use, an overlay operation can be performed to determine areas with combinations of open space land use and soil phases that are suitable for farming. The overlay feature is important because it can be used to show areas that are undesirable for the purpose the user had in mind, e.g., restricted areas overlap a soil that may be satisfactory for the use intended, as shown in Figure 1.

2. Window

To window a display means to look at only part of the total display. Thus, if the soil boundaries of Knox County are digitized and available on the system, we might want to window in on only the northeast corner of the county. If windowing were available on the system we could define a rectangle in the northeast corner of the county and display only that part of the county within the rectangle. With a subsequent window we might narrow our focus to a single soil

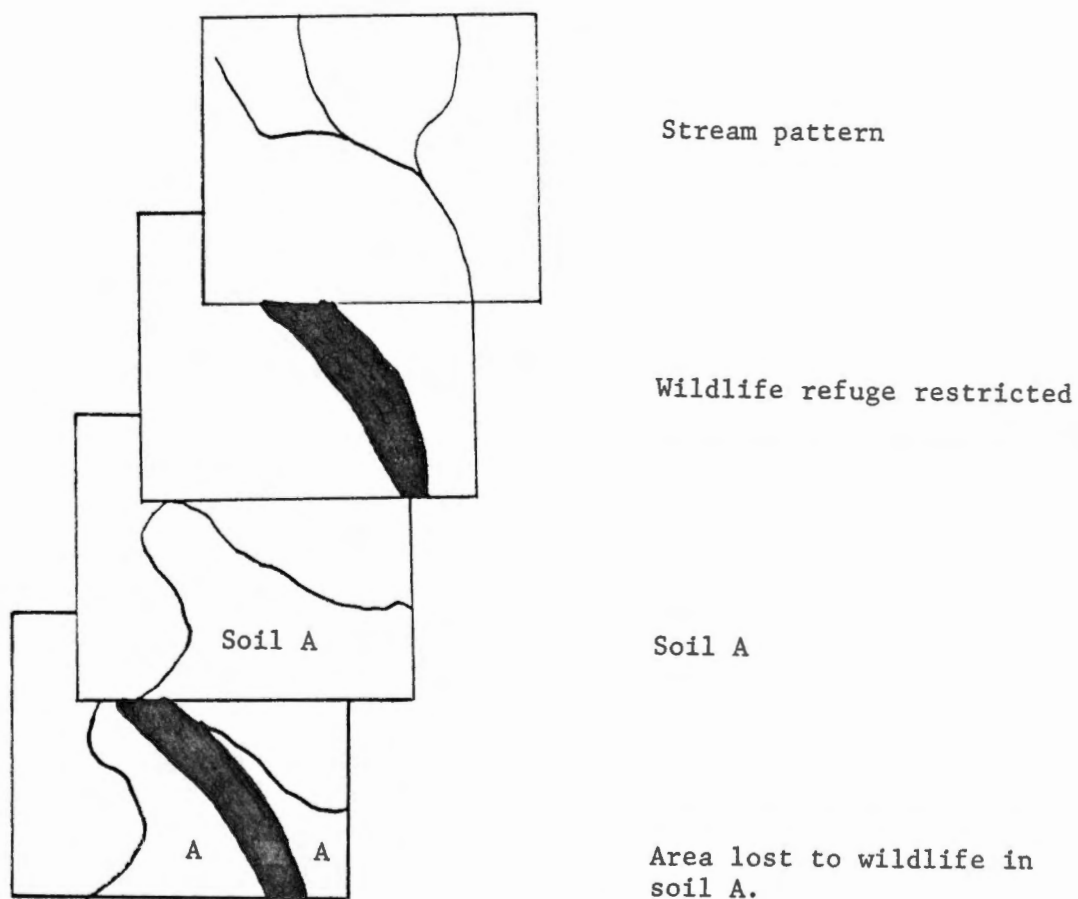


Figure 1. An example of the overlay feature. Area shown as restricted to wildlife is lost for all other uses. Adapted from COMARC Users Guide (1978).

boundary along the base of a ridge. Windowing is particularly important in interactive systems for analysis and editing.

3. Search

Search, as applied to a cell-based system, can be performed by assigning each cell a value based on its relative proximity to a specific condition or item, e.g., distance from a river or highway. Searches performed by some polygon systems are accomplished by converting polygons to cells before performing the desired search. The question generally asked when a search is performed is, what distance is a certain condition from a line or point? Is it too close or too far away from a road or stream, for example? A search can be used to determine how much is within a restricted area or how much land with a certain desirable characteristic is within a given distance of a road or stream.

4. Weight

Weighting allows the user to assign certain values based on relative importance in the overlay procedure. For example, the characteristics of a certain item may be considered 10 times more important than that of another for a specific use. The characteristics can then be weighted 1 to 10, and values assigned according to the highest value the area is weighted for. This allows the user or decision-maker to base a decision on the effects certain practices will have on a particular site.

5. Scale

Scaling allows the user to input data from unscaled source documents and scale the data within the system to fit a known base. It also allows the data to be rescaled in order to be combined with other data that may already be in the system at a different scale. Another advantage of scaling is that the output can be rescaled to assure that it will be within the limits of the printer or plotter. Not all systems have the capability to rescale data once they are encoded. The systems used in this study cannot rescale data. Although these problems are common with grid cell systems, many polygon systems have the ability to rescale data after encoding.

6. Recode

Recoding the data allows the user to reassign values within an existing map. It may be used to reduce the complexity of the overlay operation by combining various data classes.

7. Merge

Merge is used to fit adjoining maps or to merge data from separate layers into one map.

G. Computer Size

The large volumes of data generated in the processing, registration, manipulation, and storage of the input data require computers with large memories. New advances in technology have permitted the use of minicomputers and microcomputers to do jobs that

once required the use of large machines. A typical system with capabilities for processing soils information would consist of a digitizing table, cathode ray tubes, a plotter, a magnetic tape unit, an exchangeable disk drive, and a minicomputer, together with alpha-numeric terminals (Bie, 1980). The COMARC system consists of a minicomputer, a plotter, tape and storage disk, together with a menu where the user can select the kind(s) of operation(s) to be performed (COMARC Users Guide, 1978).

Results can be seen as each step is executed when using a minicomputer and a CRT unit. The same operations can be performed on large computers with a CRT attached, but higher costs can be expected. In the past, larger machines used the card method of input, and graphical displays were shown on a line printer. These procedures were performed off-line, which was unacceptable for digitizing soil information. To effectively input soil and other data for graphical displays, a continuous stream of coordinates and codes should be entered and displayed so that each step can be checked for accuracy. According to Bie (1980), on-line digitizing now dominates computer-aided soil cartography, thus reducing the need for large, expensive computers to digitize and process soil information.

H. Functions of IMGRID and MIADS

1. IMGRID

The IMGRID spatial analysis system will display on a map up to 20 variables. Since most soil legends have more than 100 units, not

all units can be mapped at once. Therefore, interpretations are mapped by assigning new values to the legend to group the soils into fewer units, usually four or five. For example, Knox County has 175 mapping units in its legend. These units are interpreted for important farmland and each was assigned to one of five classes. The classes were prime farmland, other important farmland, other land, wetness, and water. Reducing the number of units from 175 units to five made them more easily understood. All functions in IMGRID are performed through the use of keywords. The user has to make a decision about which keyword will best carry out the function intended because usually several keywords may be used to accomplish the same result. For example, XRecode and XChange can both be used to assign new values to the data. The difference is that XRecode has to follow an implied order to change each value in a file or to give it the same value, but with an XChange any value or group of values can be changed without affecting values that are to remain the same.

IMGRID has 34 keywords that perform various operations. Only 18 were used in this study: (1) ASearch, (2) End, (3) Interp, (4) Map, (5) Matrix, (6) Overlay, (7) Recode, (8) Reloc, (9) Reject, (10) Rename, (11) Search, (12) Symbol, (13) Text, (14) Update, (15) XChange, (16) XMatrix, (17) XRecode, (18) Zone. A brief description of the function of each of these keywords is in Appendix D.

2. MIADS

The Map Information Assembly and Display System (MIADS) is a method for taking descriptive maps and associated quantitative data and making them available for analysis and decision-making. MIADS uses both handwork and computer. The process starts with a source map that shows various land characteristics. Each different item of information wanted from the map, such as soils, water, and land use, is defined and given a two-character code. The use of a character system in MIADS/360 makes about 2,200 codes available. A rectangular grid is placed over the source map, and each grid cell is assigned the appropriate code. The entire map is hand coded a line at a time. The map is divided into strips for coding and display. Each row has 36 two-digit cells, two cells for map identification symbol, two cells for strip identification, and four cells for line numbers; the wider the map, the more strips—columns of lines—are required. Mapped codes are then transcribed to punch cards. The cards are then fed into a computer.

Input data - Program MI is the master file creation/update segment of the MIADS system. Its operations are implied by the system flow chart in Figure 2.

MIADS was used as flowcharted with the exception that no title cards were read into the system. The titles were put in the appropriate places using the time sharing terminal.

The next step is input data - Program M2A, the first of a three-step process. The second step is the generalized IBM sort/

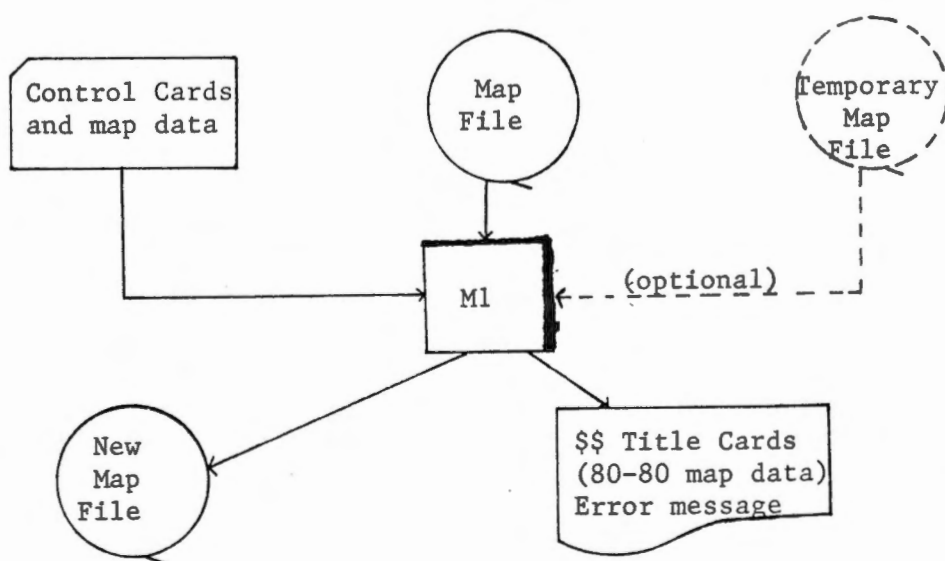


Figure 2. Flowchart that outlines the sequence of cards needed to put data into the MIADS system. Adapted from USDA Soil Conservation Service (1972).

merge program; and the third is program M2B of MIADS. This three-step process or phase is the translate/combination component of MIADS. All data manipulations and analysis functions are performed by using the two words-translation and combination. MIADS operations are implied by the system flowchart in Figure 3.

Translations and combinations were performed on the time sharing terminal instead of using the traditional card method.

The final input-program M3 designates the map to be tabulated and displayed and supplies the total area of the map. There is only one type of control card for this program. The system flowchart of program M3 is shown in Figure 4. This process was also performed on the time sharing terminal.

The series of flowcharts about the MIADS system show how translation is used to generalize the data. For example, in most soil surveys, there are 100 or more mapping units that can be generalized by making certain interpretations. Through translation in MIADS, soils with similar characteristics can be assigned to the same group to reduce the usual 100 or more mapping units to four or five units. Combination was used to combine files such as Knox County with Loudon County. It was also used to combine various kinds of resource data. For example, land use was combined with interpretations from soils such as suitability for farmland. Finally MIADS was used to produce maps and summary tables.

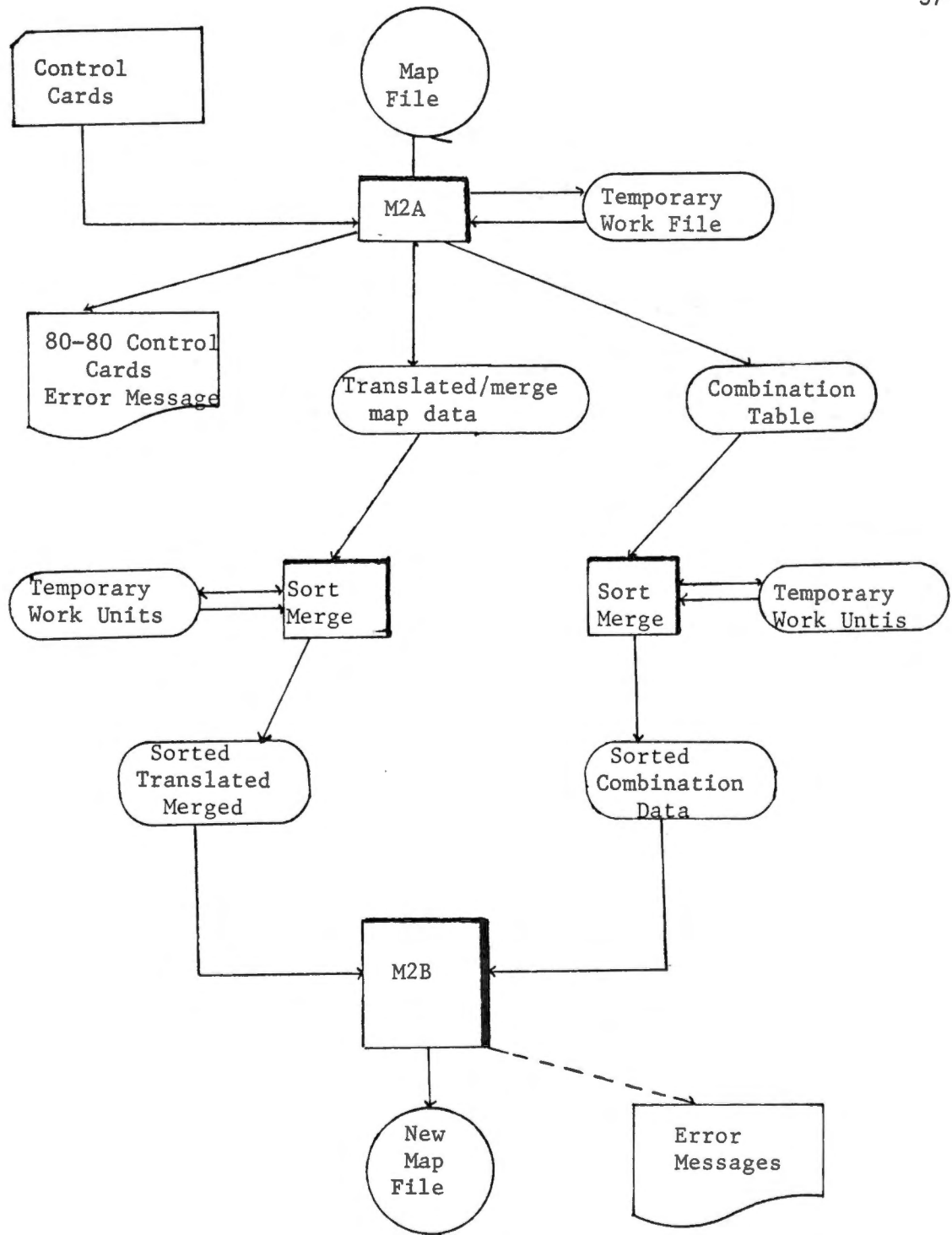


Figure 3. Flowchart showing how input data are manipulated in the MIADS system. Adapted from USDA Soil Conservation Service (1972).

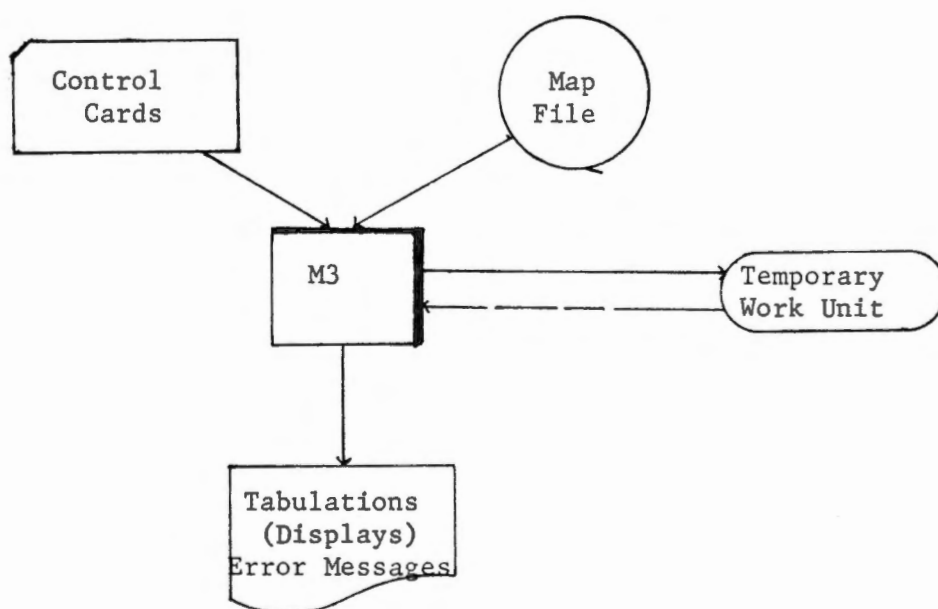


Figure 4. Flowchart showing input into file M3 to create tabulations, displays, and error messages. Adapted from USDA Soil Conservation Service (1972).

CHAPTER IV

AN EVALUATION AND COMPARISON OF SYSTEMS

A. General Criteria Defined

The purpose of this chapter is to identify some of the criteria used to examine, evaluate, and compare "off the shelf" computer software for possible use in providing accurate and complete information to aid in the decision-making process. The evaluation is based on the system's ability to meet user needs from the standpoint of: (1) data storage, (2) geographic reference, (3) data retrieval, (4) interpretation, (5) combination of data, (6) performance of analysis functions, (7) graphics, and (8) statistical output. Systems that did not have the capability to make interpretive maps, perform certain analyses, combine data, and produce graphic and statistical output were eliminated. After evaluation in this manner, final selection of two systems for this study was based on their availability for use.

1. Storage

There are many types of geographic information and as many different schemes for storing it (Thorpe, 1977). Certain storage schemes or data structures are appropriate to some types of data but not to others. Perhaps the best approach in system development is to choose simple, general schemes well suited to the type of data land use planners and researchers most use.

Geographic data, that is, data stored in association with some X-Y ground coordinate information or with some defined area, can generally be converted easily to a different type of data structure so that data from projects not designed for a particular system can be processed in that system.

In order to store resource data such as soils, the system must allow some flexibility; that is, it must be able to accept data in one or more of several forms.

a. Cells. The simplest and least expensive method of storing data is by grid cells. The main problem with grid cell representation is loss of information. The amount lost can be minimized by using smaller cells. However, the smaller cells require more time in the encoding processes, and increase the cost. Two ways of encoding resource data by grid cells are the center dot and the predominant type methods. They were discussed in Chapter III under Input of Map Data in Digital Form.

b. Polygons. This method requires a more sophisticated system and more time for the user in terms of data preparation and encoding. Several methods are being used by different workers. Some of these methods were described in Chapter III under Input of Map Data in Digital Form.

c. Lines. Resource data are represented most accurately if put into a computer system by lines. The method is more complex and requires more time for data preparation and encoding. Lines are

developed by a matrix of dots that can produce a line with data identified on both sides. Lines were discussed in Chapter III under Input of Map Data in Digital Form.

Whether lines, polygons, or cells are used, the alphanumeric characters of soils data present another problem that has to be solved. Systems which deal only with numeric characters create a problem for the user trying to input soils data. The entire soils legend has to be recoded to numeric characters. This increases the chances of error and gives the user another set of records to keep. One can see that there are problems with encoding soils data no matter which method is used to input the data.

2. Spatial References

Spatial reference systems are used in a computer-assisted land information system to systematically organize data. But it goes beyond that because land characteristics represented by the data have space as an attribute of their definitions (Beavers, 1978). For example, a soil phase defines an area of relatively uniform physical and biological properties. When a soil scientist indicates on a soil map a particular soil series and phase, a number of spatial attributes enter into the determination of the placement of the soil area. For example, inclusions, the shape of the area, minimum area limit, and distribution of spot conditions which affect potential uses of the area are some of the attributes. In a computer-assisted land information system, a spatial reference system provides a framework for expressing and representing these attributes of land characteristics.

There are several referencing systems in existence. All of them are developed by one basic process with variations based on coordinate organization, on measurement base, and on origin definition (Beavers, 1978). The three most commonly used referencing systems are: (a) the geodetic latitude/longitude, (b) Universal Transverse Mercator (UTM), and (c) State plane coordinates.

a. Geodetic latitude/longitude. The geodetic system of latitude and longitude provides a unique and continuous coverage of the earth's surface. Beavers (1978) stated that "the equator is the zero point for latitude, but there was no zero point for longitude until an international conference in 1884 established the observatory at Greenwich, England, as the ordinate meridian with the assigned value of zero degrees longitude." The unique location of any point on the earth's surface may then be located in terms of two angles (Figure 5). These two angles are the basis for the geodetic reference system.

The continuous coverage permitted by using the geodetic reference system shown in Figure 6 is important when dealing with spatial data. On the other hand, since longitude lines converge with increasing latitude, units of the geodetic system are not square or rectangular. Because the geodetic scale approximates the spherical shape of the earth, this increases the difficulty of displaying maps without distortion. However, this small amount of distortion is usually less than the precision of plotting in mapping. That the UTM

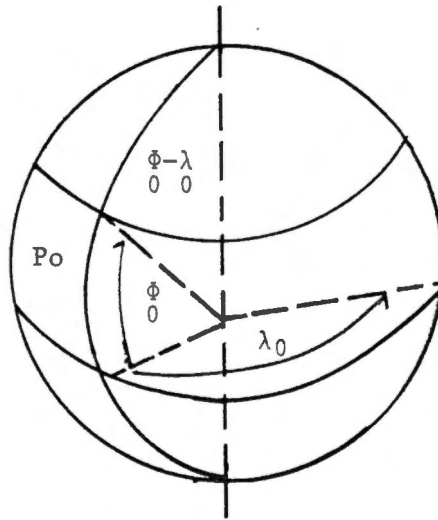


Figure 5. Geocentric based reference point. The geometric basis for a definition of a reference point on the earth's surface. Adapted from Beavers (1978).

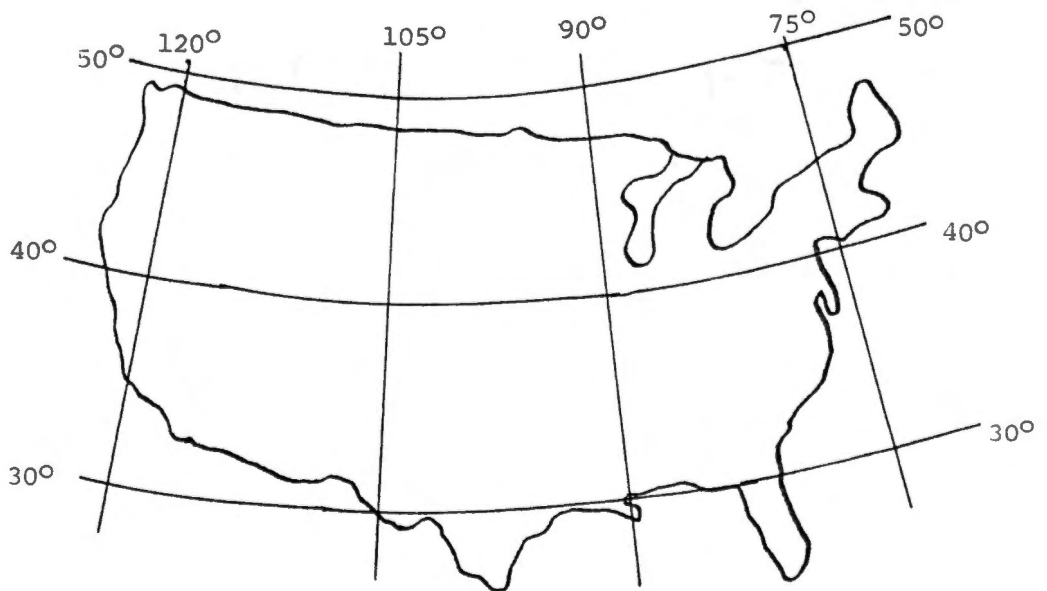


Figure 6. Large region coverage using the geodetic reference system shows continuous coverage of the United States. Adapted from Beavers (1978).

reference system and the State Plane coordinate reference system do not provide this continuous coverage of large regions is shown in Figure 7.

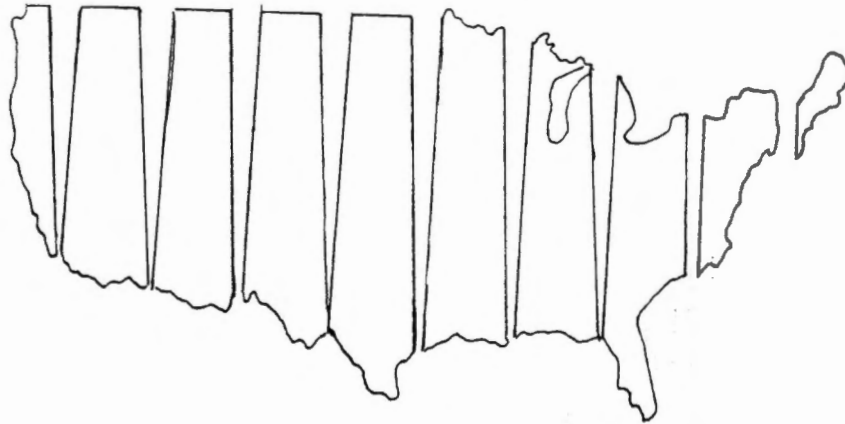


Figure 7. Large region coverage using the UTM reference system shows the UTM zone boundaries at six degrees of longitude intervals. Adapted from Beavers (1978).

b. Universal Transverse Mercator (UTM). The UTM system is a regional reference system that is extensively used in information systems in the United States. The UTM reference system is based on zone partitioning to limit scale distortion. There are nine zone boundaries across the United States at six degrees of longitude interval (Figure 7).

The UTM system design is shown graphically in Figure 8. The coordinate origin of each zone is located at the intersection of the central meridian and the equator. The zones are divided by northern and southern hemispheres. True unique location identification in UTM coordinates requires a zone number, a hemisphere designation, and

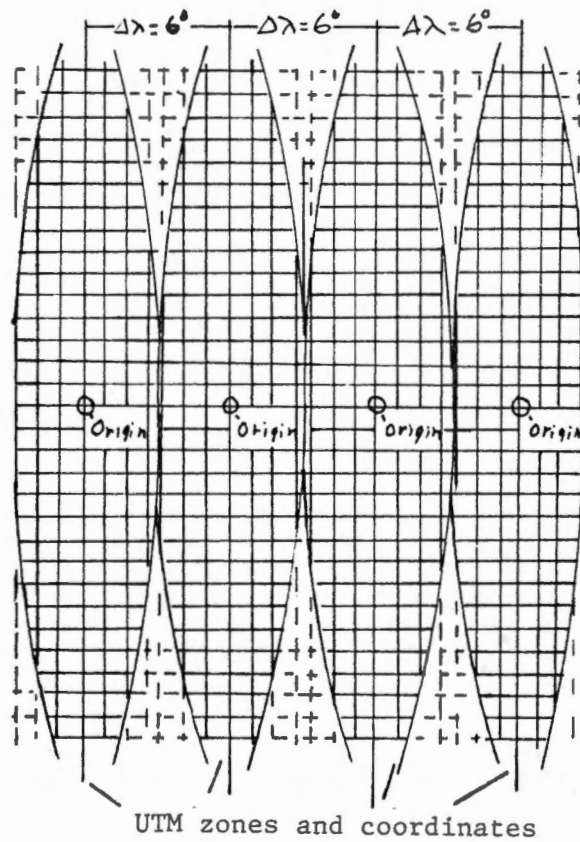


Figure 8. Multiple reference axes of the UTM reference system. Each axis is at 6° displacement with sixty reference axes covering the circumference of the earth. Adapted from Beavers (1978).

two coordinates (Easting and Northing) given in meters as determined on the transverse mercator projection and adjusted by the UTM scale factor. In many cases, the two coordinate values for points in a particular zone and hemisphere will be sufficient location identification.

c. State plane coordinates. The State plane coordinate system is similar to the UTM system in that it is a regional reference system that is used extensively in the United States. Also, it is based on zone partitioning to limit scale distortion. The State plane coordinate reference system has more than one hundred zones in its coverage of the United States. This large number of zones provides good scale accuracy throughout the coverage. However, the area and shape of most States require two or more zones for coverage. Every zone boundary marks a transition into a new zone reference system, which means that extensive computations must be made in spatial analyses involving the interface of two of these zone reference systems. This can become more complex when considering that not all zones are based on the same type of projection in the State plane coordinate reference system. For example, Florida has one zone based on a Lambert conic projection and two zones based on a transverse mercator projection. The State plane coordinate reference system is more suited to applications where required coverage is confined to one zone.

3. Retrieval

Once data have been entered into a system, an effective means of retrieval must be available. Several points that should be considered are: (a) degree of difficulty, (b) the equipment needed (CRT, printer or plotter), and (c) programs necessary for retrieval.

a. Degree of difficulty. The easier data can be retrieved from the system, the more desirable the system becomes, because most users are not computer programmers. The computer is a tool used by people with interests other than computer science as well as people with interest in computer science to manipulate and organize data to aid them in making a decision.

b. Equipment needed (CRT, printer or plotter). Some systems require specialized equipment to enter and retrieve resource data, such as the graphic CRT and various kinds of plotting devices. Since these kinds of equipment are expensive, cost should enter into selection of a particular system to be used in the handling of resource data. There are several systems that use the standard line printer and are relatively inexpensive to purchase and operate. Of course, the line printer does not offer the accuracy that is available with certain plotters or CRT units, and the printer may not give true representation of the cell unless the print is comparable to the dimensions of the cell. However, these systems are sufficient for resource data and can do the job until better or more economical systems are available.

c. Programs. Programs are a part of a computer system that can be called upon by the user to manipulate the data as desired. Some systems require more than one program to retrieve and manipulate data. These systems are structured so that some of the programs required can be handled by persons not trained in computer science.

4. Interpretations

The user must be able to make certain interpretations from the basic data. For example, interpretations from soil data might be: (a) prime farmland, (b) depth to bedrock, and (c) suitability for septic tanks. The system must be able to group soils in a manner that will show areas that are best suited for each of the uses listed as well as others an analyst might desire. Also, it must show the next best, down to areas where soils are undesirable or not suited for the purpose the user had in mind.

5. Combination with Other Kinds of Data

To make certain decisions, the user needs to know more about an area than just the capabilities of the soils. For example, information may be needed about (a) the present land use, (b) vegetation, (c) geology, and (d) distance from points to lines such as roads and streams. Because more information is sometimes needed to make the best decision, the system must be able to combine these, along with other resource data, with soil interpretations to give the user the information desired.

6. Performance of Analysis Functions

The more appropriate data a decision-maker has and the more ways these data can be analyzed, the better the chances are that the right decisions will be made. Some of the analysis functions that the system should be able to perform are: (a) search, (b) overlay, (c) window, (d) proximity, (e) weight (index), and (f) make interpretative maps. Of course, there are others that may be just as important, and the more of these functions the system can perform, the more useful it becomes. Most of the functions are discussed in Chapter III and some examples are shown in Chapters V and VI.

7. Graphic Output Capabilities

Output units are necessary and important to the graphic capabilities of a system. For example, an engineer or draftsman would desire an output unit capable of producing accurately to a thousandth of an inch or less. Such accuracy is not needed or required in resource data handling. One reason is that the input data are not that precise. The user still needs to know the limits of the system in terms of what kind or how many output devices the system can use. The line printer is most widely used because it is a standard piece of equipment in most computing centers, and systems using the line printer are usually not as complex as those that use the CRT or some kind of plotter.

8. Statistical Output

In order to evaluate the suitability of an area for a specific purpose, some type of statistical data must be presented. Information systems handle this task in various ways: (a) frequency count—some systems using grid cells simply count the number of occurrences of a particular type of data, (b) tabulation of area—other systems multiply these occurrences by the size of the cell and give an area total, (c) percentages—some systems give the percent of area occupied by each different kind of soil, for example, and (d) proportion—how much of the land is suitable for the intended use.

CHAPTER V

METHODS AND PROCEDURES

A. Preliminary Study of Systems

The initial evaluation of systems was performed by determining the usefulness of existing Geographic Information Systems (GIS) for producing interpretive maps from soils information. In an attempt to find what systems were available and what their capabilities were, a questionnaire was prepared by the researcher in 1979 and sent to 50 Soil Conservation Service (SCS) state offices, major land grant universities, and to 4 technical service centers of the SCS. There were 20 questions on this questionnaire (a copy of the questionnaire can be seen in Appendix C). Response to these questionnaires was as follows: forty-eight questionnaires were returned from the SCS with about 60% of the respondents saying that they did not use the computer to produce interpretive maps from soils information; and twenty-seven questionnaires were returned from universities with 63% saying they did not use the computer to produce interpretive maps from soils information. Although many of the respondents did not use the computer, they all expressed a desire to know what was being done in this field and encouraged this type of research.

Information was obtained on more than 100 systems from the literature and from materials received in response to the questionnaires. Many of these systems were eliminated from comparison

because they were not developed with mapping capabilities. Others were still in the developmental stages and could not be evaluated fairly during the course of this study. A preliminary evaluation of the remaining systems will be used to demonstrate the capabilities of the computer in the production of interpretive maps from soil survey information. From these data 55 systems were identified that seemed to be operational and included mapping capabilities (see Table 2).

B. Evaluation of Systems

Of this group of 55 systems left after the initial cut it was possible to identify the following characteristics for 41 systems. These systems were evaluated on the basis of the hardware needed to operate the system; the programming language in which the system was written; the mode of operation (batch or interactive); the method by which the system will accept data (cells, polygons or lines); how much memory is required to operate the system; and, more important, the availability of the system for use during the course of this study.

The 41 systems identified as having the capability to perform the required storage, retrieval, analysis and display functions are listed in Table 3. This information was assembled from literature obtained from response to questionnaires and from literature by the USDA Forest Service (1976) and the U.S. Fish and Wildlife Service (1977). There were other systems that showed some promise, but information was hard to get from the literature and from response to the questionnaires. There were indications some systems could perform

Table 2. List of 55 existing Geographic Information Systems.

System Acronym	Agency, University, or Business Organization	System Acronym	Agency, University, or Business Organization
ADAPT	W. E. Gates and Associates Batavia, OH 45103	CLAR 1	Colorado State Univ. Ft. Collins, CO
AMS	Soil Conservation Service Lanham, MD	CMS 1	EDA U.S. Dept. of Comm. Washington, DC
AUTOMAP	Environmental Systems Research Institute Redland, CA 92373	CMS II	Federation of Rocky Mtn. States Ft. Collins, CO
BNDRYNT	Ministry of Urban Affairs Ottawa, Canada	COMLUP	U.S. Forest Service Ft. Collins, CO
CADDS	Computervision, Inc. Bedford, MA 01730	COMPIS	COMARC Design Systems Lakewood, CO 80228
CAM	CIA U.S. Dept. of Comm. Springfield, VA 22151	CRIS	Bureau of Land Mgt. Denver, CO
CART 8	Instronics, Ltd. Stittsville, Ont. Canada	ECOMAP	Colorado State Univ. Ft. Collins, CO
CBMS	Soil Conservation Service Temple, TX	EPPL	Earth Systems Research, Inc. Minneapolis, MN
CGIS	Canada Land Inventory Ottawa, Ontario		

Table 2 (continued)

System Acronym	Agency, University, or Business Organization	System Acronym	Agency, University, or Business Organization
EPPL-2	Earth Systems Research, Inc. Minneapolis, MN	LIMAP	South Dakota Planning Bureau Pierre, SD
EPPL-4	Minnesota Land Mgt. Information Systems Minneapolis, MN	LUAS	National Aeronautics and Space Adm. Bay St. Louis, MS
FACTS	Purdue University Lafayette, IN	LUIS	Univ. of Massachusetts Amherst, MA
GELO	U.S. Forest Service Berkeley, CA	LUMAD	U.S. Geological Survey Reston, VA
GIM	Environmental Protection Agency, TRW Systems, Inc. Redondo Beach, CA	LUMIS	Cal Tech-JPL Pasadena, CA
GRID	Harvard University Cambridge, MA	LUMP	Univ. of California Berkeley, CA
IMGRID	Harvard University Cambridge, MA	MADPS	Montana State Univ. Bozeman, MT
INFORM	U.S. Forest Service Berkeley, CA	MAGI	Environmental Systems Research Institute Redland, CA
LIM	U.S. Forest Service Berkeley, CA	MAP/MODEL	Univ. of Oregon Eugene, OR

Table 2 (continued)

System Acronym	Agency, University, or Business Organization	System Acronym	Agency, University, or Business Organization
MIADS-2	U.S. Forest Service Berkeley, CA	PLOT	U.S. Forest Service Berkeley, CA
MIADS/360	Soil Conservation Serv. Ft. Worth, TX	RAMP	U.S. Forest Service Berkeley, CA
MSDAMP	Univ. of Iowa Iowa City, IO	R3MAP	U.S. Forest Service Berkeley, CA
OCAP	Ohio Dept. Natural Res. Columbus, OH	SAG	U.S. Fish and Wildlife Service, Ft. Collins, CO
ORRMIS	Oak Ridge National Lab. Oak Ridge, TN	STOPIN	Engineering Topo Labs, U.S. Army
PLANMAP-1	New York State LUNR Inventory, Cornell Univ. Ithaca, NY	STORET	Environmental Pro- tection Agency Cincinnati, OH
PLANMAP-2	New York State LUNR Inventory, Cornell Univ. Ithaca, NY	SYMAP	Harvard University Cambridge, MA
PLANMAP-3	New York State LUNR Inventory Cornell Univ. Ithaca, NY	TOPAS	U.S. Forest Service Berkeley, CA
		TRAS	Univ. of Massachusetts Amherst, MA

Table 2 (continued)

System Acronym	Agency, University, or Business Organization	System Acronym	Agency, University, or Business Organization
TRI	U.S. Forest Service Berkeley, CA	WRIS	U.S. Forest Service Berkeley, CA
URIS	Genessee/Finger Lake Regional Planning Bd. Rochester, NY		

Source: Information on these systems was compiled from published literature by the U.S. Fish and Wildlife Service (1977), the USDA Forest Service (1976), and from information in response to a questionnaire by the researcher.

Table 3. Summary of characteristics of selected Geographic Information Systems.

System	Hardware (CPU)	Programming Language	Operation Environment	Geographic Data Type	Required Memory
ADAPT	IBM 370 or PDP 15	FORTRAN	Batch and Interactive	IRREGULAR Triangular GRID	IBM = up to 200k bytes*
AMS			Interactive	Lines	
AUTOMAP	IBM 360	FORTRAN	Batch	Cell	240k bytes
BNDRYNT	IBM 360	FORTRAN	Batch and Interactive	Line to polygon	120k bytes
CADDS	Data General	FORTRAN	Interactive	Arc, polygon, point	128k bytes
CAM	IBM 360	FORTRAN	Batch	Point, line, polygon	250k bytes
CART 8	PDP 8c	Assembler	Interactive	Symbol, point, line, polygon	32k bytes
CEMS	UNIVAC 1100/400	COBOL	Batch	Cell	25k
CGIS	IBM 360/370	PL-1/x (Maj.)	Batch and Interactive	Line	300-1000k bytes
CMS I	UNIVAC 1108	FORTRAN	Batch	Cell	250k bytes
CMS II	IBM 360/370	COBOL	Batch	Input-Polygon or cell	
COMLUP	CDC 3100	FORTRAN	Batch	Arc	32k words**
COMPIS	Data General	FORTRAN	Interactive	Line, point, polygon	64k bytes
CRIS	CDC CYBER	FORTRAN	Batch and Interactive	Polygon	
ECOMAP	CDC 6400	FORTRAN	Batch	Cell	100k words
EPPL-2	CDC 6400	FORTRAN	Batch	Cell	60-150k words
EPPL-4	CDC 6400	FORTRAN	Batch	Cell	60-150k words
FACTS	CDC 6500		Interactive		
GELO	UNIVAC 1108		Batch and Interactive	Lines	

Table 3 (continued)

System	Hardware (CPU)	Programming Language	Operation Environment	Geographic Data Type	Required Memory
GRID	IBM 360	FORTRAN	Batch	Cell	150k bytes
IMGRID	IBM 360	FORTRAN	Batch	Cell	32k bytes
LEMS	UNIVAC 1108	FORTRAN	Batch	Points, lines, Cell	
LIM	UNIVAC 1108		Batch and Interactive		
LIMAP	IBM 360/370	FORTRAN	Batch	Landsat	
LUMAD	IBM 370	FORTRAN	Batch and Interactive	Input = line	320k bytes
LIMIS	IBM 360	FORTRAN	Interactive	Line and cell	
LUMP	Burroughs 6700	ALGOL	Batch and Interactive	Cell	
MAGI	IBM 360	FORTRAN	Batch	Cell	
MAP/MODEL	IBM 360/370	FORTRAN	Batch	Polygon	113k bytes
MIADS - 2	IBM 7040	FORTRAN	Batch	Alpha, cell	64k bytes
MIADS/360	IBM 360	FORTRAN	Batch	Alphanumeric cell	
MSDAMP	IBM 360	FORTRAN	Batch	Cell	
OCAP	IBM 360	PL/1	Interactive	Line segment	
ORRMIS	IBM 360/370	FORTRAN	Batch	Hierarchical/ cell	210k bytes
PLAN MAP 3	IBM 2316		Batch and Interactive	Cell	
PLOT	IBM 370		Batch and Interactive	Polygon	
R3MAP	UNIVAC 1108		Batch and Interactive	Cell	
SAG	CDC 6400	FORTRAN	Interactive	Polygon	50k words
STOPIN	CDC 6600	FORTRAN	Batch and Interactive	Alpha	75k words

Table 3 (continued)

System	Hardware (CPU)	Programming Language	Operation Environment	Geographic Data Type	Required Memory
TOPAS	UNIVAC 1110	FORTRAN	Batch and Interactive	Digital/terrain	
WRIS	UNIVAC 1110	FORTRAN	Batch	Polygon	

*Byte: A sequence of adjacent binary grids operated upon as a unit and usually shorter than a computer word.

**Word: An ordered set of characters which occupies one storage location and is treated by the computer circuits as a unit and transferred as such.

a certain function, but there was no explanation as to how it was done. Nor was there any information on how data entered the system or the kind of equipment needed. Some of the systems were developed by people outside the agency or university. Response to the questionnaires indicates that the users did not understand how these systems were put together. Such systems were eliminated from further study. Other systems were eliminated because they were not accessible and did not have enough soils data encoded to judge their efficiency in dealing with soil data.

C. Selection of Systems

MIADS and IMGRID were selected because they had the capability to produce interpretive maps from soils data and were available for use in this study. Characteristics of these two systems are shown in Table 4. Since both MIADS and IMGRID are grid cell systems a special effort was made to acquire the use of the COMARC system which utilizes polygons. This idea was abandoned when it was learned that the SCS in North Carolina had been trying unsuccessfully for more than a year to produce interpretive maps using the COMARC system. For these reasons the MIADS and IMGRID systems were the only two available for comparison.

The computer systems IMGRID and MIADS were selected to demonstrate the capabilities of a spatial analysis system for several reasons: (1) both systems were available and accessible for

Table 4. A comparison of the IMGRID 2.5 and MIADS/360 systems showing how data are processed by the two systems in 1979.

	Common Characteristics	
	IMGRID	MIADS
Data Base	Cell	Cell
Data Input	Row	Row Strip
Control Information	Keyword	Keyword
Discrete Lines	Yes	Yes
Discrete Point	Yes	Yes
Processing Mode	Batch	Batch/Interactive
Graphic Display	Line Printer	Line Printer
Statistical Summary	Frequency Counts	Tables
Error Detection	Execution	Execution
Resolution	Grid Cell	Grid Cell
Data Editing	Yes	Yes
Data Storage	Disk	Disk
Core Requirements	32K Bytes	64K Bytes
Windowing	No	No
Data Recoding	Yes	Yes
Scale Modification	No	No
Overlay Maps of Different Scales	No	No
Composite Mapping	Yes	Yes
Information Display	Yes	Yes
Catalog of Map Data	Yes	Yes
Island Processing	No	No
Map Display	Value or Shaded	Value
Geographic Coordinates Available	No	No
Minimum Area	Grid Cell	Grid Cell
Map Size	32,500 Cells	36-Two Character Strips (Infinite Length)
Proximity (Distance)	Yes	No
Max. Number of Shades	20	None
File Correction with- out Total Replacement	Yes	Yes

the researcher's use, however, for program security MIADS was operated by SCS personnel and it was available for use in this research only if data were prepared and given to the SCS for processing; (2) both systems have been used successfully for producing interpretive maps from soil information; (3) the SCS and TVA have a cooperative agreement, and show interest in a comparison of the systems; and (4) if both agencies could use the same system or compatible systems some problems with shared information could be eliminated.

The reasons polygon systems were not chosen for this study are: (1) they are relatively new with little or no soils information encoded; (2) there was no polygon system accessible to the researcher; and (3) company literature obtained on these systems was not encouraging from a users standpoint.

The information needed to demonstrate the capabilities of the two systems was collected and encoded by the researcher. All key-punching was done at TVA's data processing unit. Soils and other information were stored on both the IMGRID and MIADS systems and checked for errors. For the IMGRID system known errors were corrected and all of the maps were produced by the researcher. For the MIADS system known errors were corrected by the researcher, but all other operations of the system were performed by SCS people on the time sharing terminal.

D. Selection of Study Area

A five-minute section of the southeast corner of the Concord seven and one-half minute quadrangle located in the Valley and Ridge

physiographic region of east Tennessee was selected for study (see Figure 9). The area has published soil surveys and provided an excellent opportunity to deal with some of the problems that are encountered when computerizing resource data, especially soil data. Some anticipated problems were:

1. Parts of three counties, Loudon, Knox, and Blount, lie in the study area. The soil surveys for each are published at scales of 1:15,840, 1:24,000 and 1:20,000, respectively.
2. Problems of overlap and lack of information along the three county boundaries.
3. Inaccuracy of the base maps for the three-county area.
4. Conflicts may occur when resource data from one base map are combined with that from another. For example, when soils from the soil survey map are combined with land use from a topographic base some conflicts between water and land can be expected, because of distortion in the photograph or errors in the topographic map.
5. Some encoded data may not be used by all systems because of the inability of some systems to perform certain analysis. For example, road and stream data were not used in MIADS because the system cannot do proximity.
6. The time required and high cost of placing resource data into a computer-readable format for some systems. The true cost of computerized data analysis was hard to predict because no one really wanted to say how much it would cost to use their computer.

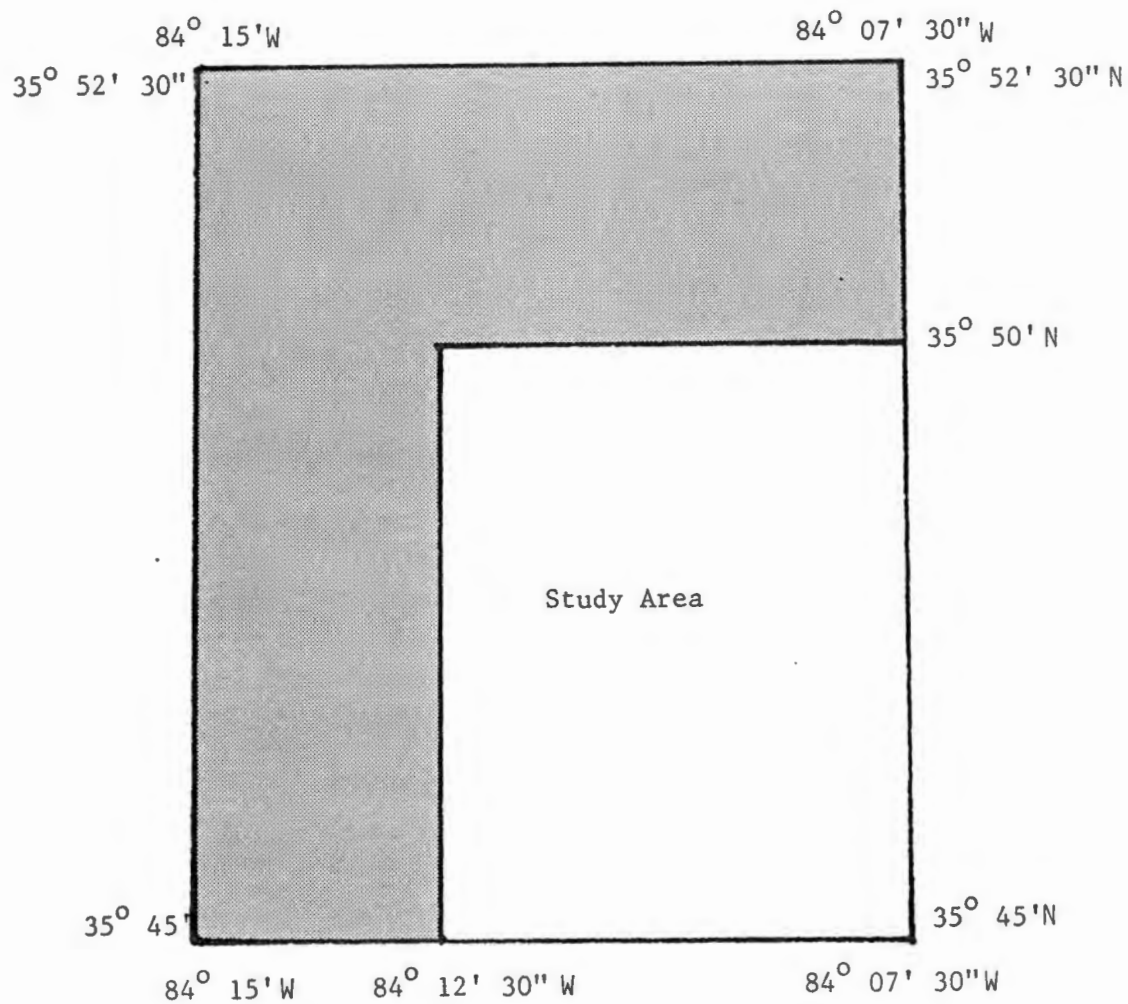


Figure 9. The portion of Concord quadrangle selected for the study area.

E. Data Acquisition

The kinds of maps to be produced and the analyses to be made had to be determined before the data gathering process began. It was decided to include the kinds of information that resource planners need most such as: (1) present land use, (2) soils of the area, (3) roads, and (4) surface water (lakes and streams). Then it was decided how each of these would be used alone and in combination with other information. For example, the soil data would be used to produce interpretive and single factor maps such as: (1) suitability for farmland, (2) depth of bedrock, (3) land capability classes, (4) sanitary landfill potential, (5) erosion potential, and (6) slope.

Interpretive maps such as suitability for farmland and land use would in turn be combined with other resource data to produce other maps to show the utilization of farmland and farmland lost to development. Also, sanitary landfill interpretations could be combined with land use to show sites suitable for landfill that do not conflict with development. Finally, it would be possible to show areas that were within five cells 576 m (1891 feet) north/south and 470 m (1542 feet) east/west or greater than three cells 346 m (1134 feet) north/south and 282 m (925 feet) east/west from a certain condition. For example, combination of sanitary landfill interpretations with searches from roads, development, and water would show sites that were suitable for a sanitary landfill, close to roads, and far from development and water.

1. Preparation of Information for Encoding

Materials needed for the study area were soils information for the area, a map showing roads and streams, and a base map for showing present land use. The Blount County soil information was obtained from the Blount County soil survey by Elder et al. (1959). Other soil information was taken from the Knox County soil survey by Roberts et al. (1955), and the Loudon County soil survey by Elder et al. (1961). Roads and streams were taken from the U.S.G.S. topographic sheet, revised 1968, which also served as the base for land use. Light duty and medium duty roads were selected. Some combinations of roads and streams were necessary to cover all conditions needed for the study. These classes are: medium duty roads, light duty roads, perennial streams, medium duty roads and perennial streams, and light duty roads and perennial streams. The criterion for streams was that they be at least 5 cells long. In the latitude in which the study area is located 5 cells are equal to approximately 576 m (1891 feet) north/south and approximately 470 m (1542 feet) east/west. After reviewing the maps generated by the program it was found that several errors were made while encoding roads and streams from the topographic map. Some are: (1) a stream 6 cells long located about 1067 m (3500 feet) southeast of the point where Beals Chapel road makes a sharp turn located just north of the 605 river mile marker was not encoded, (2) a stream 6 cells long located about 305 m (1000 feet) north of the same point identified on Beals Chapel road was not encoded, (3) a stream 5 cells long located near and west of the junction of Disco road and Parks Ferry

road was omitted, (4) a light duty road 5 cells long located about 610 m (2000 feet) west of Smoky Landing dock was encoded but does not exist, and (5) a light duty road eleven cells long located about 1067 m (3500 feet) north of the Sequoyah Heights subdivision was not encoded. When these features were checked on the maps in which the roads and streams had been used, it was determined that these minor errors would not materially affect the final result. Therefore, it was decided to leave maps in the current form, but point out the errors so that any reader would be aware of them in case the data were to be used for purposes other than this study. Furthermore, it was determined that many streams shown as perennial on the topographic map are really intermittent.

The omissions listed above can be located on the computer map by cell number. There are 6400 cells in the study area. Number the cells beginning at the upper left corner of the roads and streams on the computer map, proceeding left to right until all cells are numbered. Using the numbering system described the computer map for roads and streams have the following cells missing: (1) a stream 6 cells long was omitted; the cell numbers are 4412, 4413, 4492, 4572, 4651, and 4731, (2) a stream 6 cells long was omitted; the cell numbers are 4086, 4087, 4165, 4166, 4167, and 4168, (3) a stream 5 cells long was omitted; the cell numbers are 3566, 3646, 3647, 3727, and 3807, (4) a light duty road 5 cells long at cell numbers 4619, 4620, 4621, 4622, and 4623 does not exist, and (5) a light duty road 11 cells long was omitted; the cell numbers are 3877, 3957, 4037,

4116, 4196 to 4200, 4280, and 4281. In order to locate these cells on the computer map of roads and streams it was necessary to construct a grid by drawing a series of horizontal and vertical lines.

The soil surveys of Blount County and Loudon County are of the modern type with maps published in book form on folded photo base sheets. These sheets were spliced together to obtain solid coverage of the study area. Also, the boundary of the study area was outlined on the maps after they had been spliced together. Knox County was on a topo base with the county boundary line already on the map. After combination and checking of the soil maps, they were ready for the encoding process.

The land use was determined by using an aerial photograph (1975) and a topographic map (1968) and actually driving down the roads in the Spring of 1979 to observe land use for recording on an aerial photograph. The area that could be seen from the roads was again field checked in August, 1979. All maps produced by IMGRID used 1979 land use except one. The area northwest of Fort Loudon Lake in the study area was interpreted from the photograph and used in the MIADS system as 1975 land use. However, some of the data on the MIADS map is similar to 1979 land use except for the part northwest of the lake in the study area.

Land use data were transferred to a topographic map because the aerial photograph, although the same scale, did not overlay exactly due to distortion and poor scaling. The classes chosen for the land use map were: (1) cropland, (2) grassland, (3) woodland,

(4) roadside residential, (5) commercial, (6) public and semipublic land including parks and cemeteries, (7) idle land, (8) subdivisions, (9) towns, and (10) water. Cropland was defined as land presently under cultivation. Grassland is pasture or hayland. Idle land shows no particular use at the present, but was formerly used as cropland or grassland. Public and semipublic land includes parks, cemeteries, and any other public use of land. Roadside-residential was defined as areas with four or more houses per 805 meters (half-mile) of road. Subdivisions were residential developments with formal names such as Crestwood Estates. Woodland as defined by the U.S. Forest Service is land with more than 16.7% tree cover. Towns are defined as rural or urban units of local government smaller than a city. However, in this research towns mean only the populated area as outlined by the researcher, not the incorporated boundaries. Commercial is defined as land used to house products that are sold for profit. The term water is used for perennial streams, lakes, and ponds where water stands for most of the year.

2. Encoding Resource Data

The soils data are on maps of different scales: 1:15,840 for Loudon County, 1:24,000 for Knox County, and 1:20,000 for Blount County. All other data were recorded at a scale of 1:24,000. In order to encode the data, a grid had to be selected or generated to fit the scale of map to be encoded, if one was not on file. The necessary grids were in the file at TVA.

The center dot method of encoding a grid that had a dot in the center of each 1.08 hectare cell (2.68 acre) was used as recommended by McCroskey (1975). The information that falls directly under the dot is recorded for that cell. One advantage of this method is that no decision has to be made as to what makes up the greatest portion of that cell. Soils data for the three counties were encoded with care to take out the overlap that may have occurred because of distortion in the base or because the lines between counties were not drawn in the same place. This caused some of the area between Loudon and Blount counties to be void of soil information. For the IMGRID system this area was given a special symbol. The MIADS system filled this void with characters from the county boundary map. Land use was encoded in the same manner as soils data.

Roads and streams were coded as being either present or absent in a cell on a grid with enclosed cell boundaries. The present/absent method was used to encode roads and streams because of the need to know if either passed through the cell. However, the dimension of the cells exaggerates the existence of roads in the study area. In the latitude in which the study area is located a cell is about 115 m (378 ft) north/south and approximately 94 m (308 ft) east/west. As with roads, area of streams which are rarely more than 6 m (20 ft) wide is greatly exaggerated by the size of the cells. These two methods may cause site specific data to be omitted. However, since these methods were developed for sampling data, in either case the sample will be representative.

The time involved in preparation and encoding is presented in Table 5.

Table 5. Time required for preparing and encoding spatial data for a five minute portion of the Concord quadrangle.

	Preparation	Soil Encoding	Other Encoding	Total
	hrs			
MIADS	8	26	18	54
IMGRID	11	24	27	62

3. Data Validation

Upon completion of the encoding process, the data were loaded into the systems and checked for errors. Once the keypunching and coding errors were removed, the data were mapped and visually scanned to aid in locating and correcting errors. When reasonably sure that all errors had been corrected the data were ready for mapping and for other analysis functions. Of course, there is always a chance that errors will be found in the data and maps after numerous revisions. If errors are found in the data or maps they can be corrected more easily with computer techniques than with manual techniques.

F. Preparation of Maps

1. MIADS

In this research, a dot grid, instead of a rectangular grid normally used by the SCS, was placed over the source map. This method was chosen because dot grids were already available at the desired scale and size. The data for MIADS are normally recorded on the grid itself, but data from the dot method are recorded on coding forms that are then transcribed to punch cards. The center dot procedure takes more time for the encoding process and increases the chance for making errors because of handling two items, the grid and the coding form, but coding forms are easier for keypunch operators to handle and may cause fewer keypunching errors. Data are entered into the MIADS system by strips that are 36 two-character cells wide. Three strips are necessary, but not all of the

third strip was used because the study area was only 80 cells wide. The data were input a line at a time as described previously.

2. IMGRID

The keywords of IMGRID were used to make all the analyses and maps that were produced by IMGRID. All data were entered initially into the system by use of the Interp keyword. The Update and Zone keywords were then used to edit the data. In IMGRID most of the work of changing data in a file has to be done in workspace. The Reloc keyword was used to move all the data from workspace back to what is known as semiprotected space. Workspace is defined as space where all analyses and changes in the data are made. Semiprotected space is storage for data that are to be kept. The Rename keyword was used to rename a file that was not titled on the end run list. The Overlay keyword was used to put fragments of three county soil maps together to produce the entire study area.

IMGRID allowed the user to map values 0-19, but Knox County, for example, has 175 values in the legend. The XRecode keyword was used to group these values into five to eight groups. The Recode keyword was used to correct some errors such as recording to fives those values of six assigned during the XRecode. This was necessary because the wrong values had been assigned to some units in the legend.

IMGRID had six symbol sets stored when the file was created but the Symbol keyword allowed the user to put desired symbols on each map. The Text keyword allowed the user to write some explanatory

remarks about the graphic display of the desired element. The Search keyword was used to identify cells that were within or greater than a specified number of cells from a specified condition. The Reject keyword was used to reject a specific condition, for example, a five cell buffer zone around the study area. The Matrix and XMatrix keywords were used to combine land use data with sanitary landfill interpretations and suitability for farmland interpretations. They were also used to combine searches from roads, water, and development with landfill interpretations. The End keyword was used last in each job because it stopped execution, stored current data files, and produced an end run list showing what was in a file and where it was located. Although not a keyword, Endt is very important because it signals where text ends and a new keyword begins.

G. Analysis Function

Composite maps and models shown in this study were produced with with the MIADS and IMGRID spatial analysis systems by combining the data in the manner demonstrated in Figures 10 through 18. A matrix was set up for the MIADS system to combine land use and suitability for farmland. This matrix is shown in Figure 10. MIADS fills the matrix with characters that are specified by the user and then maps all characters if necessary. A matrix was also set up for IMGRID to combine land use and suitability for farmland. IMGRID fills in the matrix by starting at the upper left-hand corner and proceeding left to right until the matrix is filled. The data are

Farmland Interpretations		11	22	33	44	55
Land Use	CL	AA	AB	AC	AD	AE
	GL	GA	GB	GC	GD	GE
	WL	WA	WB	WC	WD	WE
	IL	IA	IB	IC	ID	IE
	SD	SA	SB	SC	SD	SE
	TS	TA	TB	TC	TD	TE
	PS	PA	PB	PC	PD	PE
	WW	WA	WB	WC	WD	WE
	RR	RA	RB	RC	RD	RE
	CM	CA	CB	CC	CD	CE

LEGEND

Farmland Interpretations

11 = Prime farmland
 22 = Other important farmland
 33 = Other land
 44 = Wetness limitations
 55 = Water

Land Use

CL = Cropland
 GL = Grassland
 WL = Woodland
 IL = Idle land
 SD = Subdivisions
 TS = Towns
 PS = Public/Semi-Public
 WW = Water
 RR = Roadside-residential
 CM = Commercial

Values created by the matrix are assigned as the map symbols for display in the MIADS system.

Figure 10. Matrix suitability for farmland and land use to show how farmland is being utilized. MIADS.

		Farmland Interpretations				
		1	2	3	4	5
Land Use	CL	2	6	1	1	1
	GL	3	7	1	1	1
	WL	4	8	1	1	1
	RR	5	9	1	1	1
	PS	5	9	1	1	1
	TS	5	9	1	1	1
	CM	5	9	1	1	1
	SD	5	9	1	1	1
	WW	1	1	1	1	10
	IL	3	7	1	1	1

LEGEND

Farmland Interpretations

- 1 = Prime farmland
- 2 = Other important farmland
- 3 = Other land
- 4 = Wetness limitations
- 5 = Water

Land Use

- CL = Cropland
- GL = Grassland
- WL = Woodland
- RR = Roadside-residential
- PS = Public/Semi-public
- TS = Towns
- CM = Commercial
- SD = Subdivisions
- WW = Water
- IL = Idle land

Recoded Matrix Values

- 1 = Not suited
- 2 = Cropland on prime
- 3 = Grassland and idle on prime
- 4 = Woodland on prime
- 5 = Other uses on prime
- 6 = Cropland on other important farmland
- 7 = Grassland and idle on other important farmland
- 8 = Woodland on other important farmland
- 9 = Other uses on other important farmland
- 10 = Water

Figure 11. XMatrix suitability for farmland and land use to show how farmland is being utilized. This matrix produced values 1-50 that are recoded to values 1-10 using the XRecode keyword of IMGRID.

		Farmland Interpretations				
		1	2	3	4	5
Land Use	CL	5	5	5	5	4
	GL	5	5	5	5	4
	WL	5	5	5	5	4
	RR	1	2	5	5	4
	PS	1	2	5	5	4
	TS	1	2	5	5	4
	CM	1	2	5	5	4
	SD	1	2	5	5	4
	WW	4	4	4	4	3
	IL	5	5	5	5	4

LEGEND

Farmland Interpretations

- 1 = Prime farmland
- 2 = Other important farmland
- 3 = Other land
- 4 = Wetness limitations
- 5 = Water

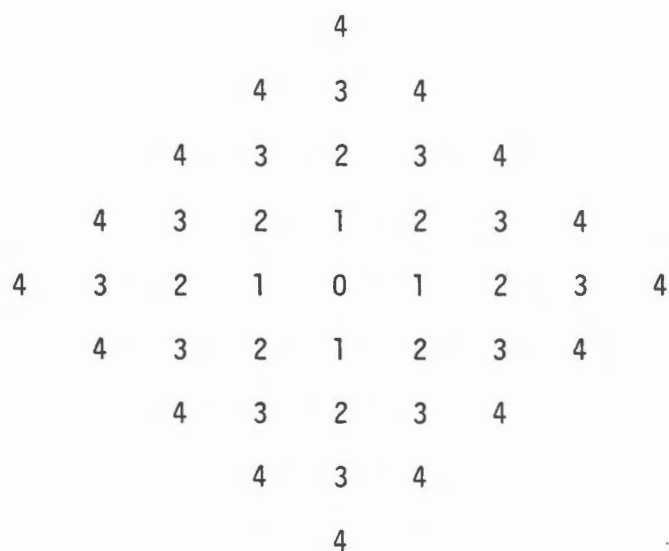
Land Use

- CL = Cropland
- GL = Grassland
- WL = Woodland
- RR = Roadside-residential
- PS = Public/Semi-public
- TS = Towns
- CM = Commercial
- SD = Subdivisions
- WW = Water
- IL = Idle land

Recoded Matrix Values

- 1 = Prime farmland developed
- 2 = Other important farmland developed
- 3 = Water
- 4 = Land and water conflict
- 5 = Other land

Figure 12. XMatrix of suitability for farmland and land use to identify farmland lost to development. IMGRID.



LEGEND

Search Keyword

- 0 = Origin
- 1 = One cell away from origin
- 2 = Two cells away from origin
- 3 = Three cells away from origin
- 4 = Four cells away from origin

Figure 13. An illustration of the diamond pattern searched by the Search keyword of IMGRID. Zero is the origin of the condition being searched from.

		Search From Roads	
		1	
Landfill Limitation	1	1	
	2	2	

LEGENDSearch From Roads

1 = Roads

Landfill Limitations

1 = Slight

2 = Moderate

Matrix Values

1 = Slight limitations close to roads

2 = Moderate limitations close to roads

Figure 14. Matrix search from roads and sanitary landfill interpretation.

		Search From Development	
		1	2
Landfill Limitation Within 5 Cells of Roads	1	1 ⁰	2 ¹
	2	3 ⁰	4 ²

LEGENDSearch From Development

1 = Within 3 cells of development
 2 = More than 3 cells away from
 development

Landfill Limitations

1 = Slight
 2 = Moderate

Recoded Matrix Values Raised

0 = Close to development
 1 = Slight limitations away from development
 2 = Moderate limitations away from development

Figure 15. Matrix search by IMGRID from development and potential landfill sites within 5 cells of roads. Recoded values are superscripted.

		Search From Water	
		1	2
Landfill Limitation Within 5 Cells of Roads and 3 Cells From Development	1	1 ⁰	2 ¹
	2	3 ⁰	4 ²

LEGEND

Search From Water

- 1 = Within 3 cells of water
2 = More than 3 cells away
from water

Landfill Limitations

- 1 = Slight limitations
2 = Moderate limitations

Recoded Matrix Values Raised

- 0 = Close to water
1 = Slight limitations away from water
2 = Moderate limitations away from water

Figure 16. Matrix search by IMGRID from water and potential landfill sites within 5 cells of roads and greater than 3 cells from development. Recoded values are superscripted.

0	0	0	0	0	0	0
1	1	1	1	1	1	0
1	1	1 ¹²	1 ¹¹	1 ¹⁰	1	0
1	2	2 ¹⁵	2 ¹³	1 ¹¹	1	0
1	2	2 ¹⁸	2 ¹⁵	1 ¹²	1	0
1	2	2	2	1	1	0
1	1	1	1	1	1	0

LEGEND

ASearched Landfill Limitation

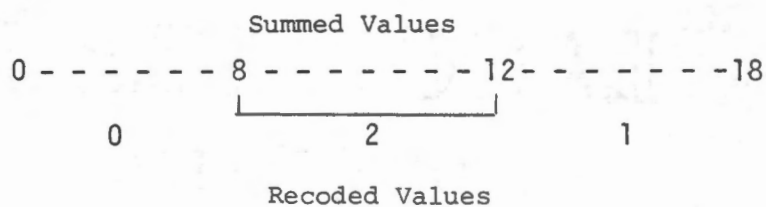
0 = Not suited

1 = Moderate limitations for sanitary landfill close to roads, away from development and water

2 = Slight limitations for sanitary landfill close to roads, away from development and water

Superscript values are the sum of the values of that cell and the values of the adjoining cells.

Figure 17. An example of an ASearch by IMGRID to clump cells that may be suitable for a sanitary landfill.



LEGEND

ASearch Keyword Plot

0 to 18 = Range of ASearch with highest value of two.

Recoded Values

- (0 - 8) Not suited = 0
- (9 - 12) Moderate limitation = 2
- (13 - 18) Slight limitation = 1

Figure 18. Recoded values of the ASearch for selection of landfill sites.

then recoded to reduce it to a limit that the user can understand and to get it within the limits that the system can map. The matrix for IMGRID is shown in Figure 11. All of the matrixes 10 to 15 were necessary to produce the maps shown.

The first matrix, Figure 10, is a combination of suitability for farmland and land use. This matrix shows how unique letter combinations were created to be used as symbols on the MIADS line-printer map of utilization of prime and other important farmland. The two character codes above the matrix represent prime farmland (11), other important farmland (22), other land (33), wetness limitation (44), and water (55). The two character codes listed vertically alongside the matrix represent land use: cropland, grassland, woodland, idle land, subdivisions, towns, public and semipublic, water, roadside-residential, and commercial uses. The two character codes within the matrix are created symbols representing combinations of suitability for farmland and land use. For example, combination of prime farmland (11) with cropland (CL) is represented by AA. Further, IC represents combination of idle land (IL) and other land (33). The map created as a result of this matrix is shown in the results and discussion under MIADS. All maps created by the various matrixes will be shown in the appropriate places in the discussion.

The second matrix, Figure 11, makes the same combinations as Figure 10 except it was created for the IMGRID system. The classes for suitability for farmland and land use are the same. However, the order of the land use classes has been inadvertently rearranged. As stated before, IMGRID filled the matrix by beginning in the upper left-hand corner

and moving left to right until the matrix was filled. This method created 50 unique classes. Since IMGRID can map only 20 classes, it was necessary to recode the classes. Values shown in Figure 11 are the recoded classes. Since the interest was in sites where prime and other important farmland were being used as cropland and other uses everything else was rated not suited except water. Originally the system produced values 1-50. These values were then recoded to produce the values shown in Figure 11. For example, the first block in the matrix is prime farmland and cropland given a value of 1 by the system which was recoded to a value of 2 to show cropland on prime farmland. Further, the second block vertically in the matrix is prime farmland and grassland given a value of 6 by the system and recoded to a value of 3 to show grassland on prime farmland. The entire matrix was recoded in this manner until all 50 unique characters were given values 1-10.

The third matrix, Figure 12, was used to create an IMGRID map that would show how much prime and other important farmland had been lost to development. Such land has commercial and residential development and may not be recovered easily for farming. Figure 12 is similar to the two preceding matrixes except it was recoded to produce an IMGRID map that would show land formerly suitable for farming that now has been developed.

Figure 13 shows a step in the development of the sanitary landfill model. The Search keyword of IMGRID can be used to show proximity to lines and points. Searches can be performed from a

point called the origin and indicated by a zero in this figure. Numbers in four directions from the origin represent the distance in number of cells. However, a diamond shape is created by this keyword because diagonals from the origin are labeled 2 and 4 rather than 1 and 2 and do not indicate distance from the origin.

Figures 14, 15, and 16 are matrixes of searches from roads, development, and water that were used to produce maps by the IMGRID system that show potential landfill sites that are close to roads and away from development and water. However, some areas were too small to be considered seriously as a satisfactory landfill site. The map would be easier to use if these small areas were eliminated by clustering or clumping only those cells which would give a value equal to 8 or more. The ASearch keyword of IMGRID can be used to do this. Figure 17 shows that the ASearch keyword of IMGRID was used to sum the values of each cell and adjoining cells. All cells except slight and moderate limitations (1 and 2) for a sanitary landfill were given a value of zero for the ASearch. Therefore, the highest possible value was eighteen. In order to obtain high values for the best sites it was necessary to recode the data making slight and moderate limitations two and one, respectively. The values 13 to 18 had slight limitations for sanitary landfill, values 8 to 12 had moderate limitations, and values of 7 or less were unsuited for landfill development. These values were then recoded as shown in Figure 18, because all other interpretive maps in the landfill model show "1" as being the best condition.

CHAPTER VI

RESULTS AND DISCUSSION

A. MIADS

The MIADS system was used rather sparingly for comparison with IMGRID. Any MIADS operations had to be performed by Soil Conservation Service (SCS) staff people at the state office in Nashville because the computer was not directly available to the researcher. For this reason, only enough maps were produced by MIADS to show the capabilities and limitations of the system.

The SCS had never handled data in the manner required for this study. For example, among the three counties different legends used the same symbol for different soils. The SCS had been handling this problem by standardizing the legends before encoding. Since part of our problem was to test each system's ability to join two or more counties to produce one map, each county had to stand on its own legend. To be able to combine different legends is important because soil surveys are produced and encoded by county format by both the SCS and TVA. A county approach is satisfactory for some purposes, but project areas rarely conform to county boundaries. Therefore, it is imperative that a system be able to use data already encoded according to each county legend.

A soil map combining the three counties could have been produced because MIADS has the capability to map 2,200 characters (USDA, Soil Conservation Service, 1972). However, such a map would contain many errors because in some cases, the same symbol represents a different kind of soil in another county. Certain maps were not produced with MIADS because of the large number of cells that would have to be processed and the amount of time it would have taken to translate codes for production of interpretive maps. This would have required too much time of the SCS personnel.

1. County Boundaries

The county boundary map was produced to show the location of three areas. In this case the areas identified were parts of three counties, but this method could be used to outline watersheds or any other area that the user wishes to identify. From this map, MIADS has the capability to pull out an area identified by the boundaries and to perform analyses on that area alone. This capability was not demonstrated in this study because data were already in the system by county and were available for analysis by each of Blount, Knox, and Loudon counties.

Figure 19 is an example of the county boundary map. The legend shown on the map was added from another printout. Legends for the MIADS system are printed on different pages. Table 6 gives the area distribution by counties as determined by MIADS. The map and table show that Loudon County makes up the largest portion, 43%,

Table 6. Counties in the Concord study area—area distribution determined from MIADS system output.

Classes	Code	Cells	Hectares	Acres	%
Blount County	BL	2414	2618	6470	37.7
Knox County	KX	1236	1341	3313	19.3
Loudon County	LN	2750	2983	7370	43.0

of the study area. A similar map could have been produced by the IMGRID system. To delineate areas with IMGRID all areas must be encoded, each boundary must be identified by the cells that make up the boundary, and everything else rejected by using the Reject keyword. Individual county maps produced with IMGRID are discussed later in this chapter.

2. Land Use

Figure 20 is a map produced with MIADS to show how part of the study area was used in 1975 and how another part was used in 1979. For the area northwest of the main channel of Fort Loudon Lake land use was interpreted from a 1975 aerial photograph. The area southeast of the lake was field checked in the spring of 1979 to determine land use.

In the fall of 1979 land use of the entire study area was field checked. The IMGRID map shows this updated 1979 land use. Since on the MIADS map the area northwest of the lake shows 1975 land use and was not updated, comparison of MIADS and IMGRID maps for this section shows changes in land use. Some grassland was converted to subdivision between 1975 and 1979. One reason for not updating the MIADS map was because MIADS was operated on the SCS computer in Nashville. Each set of changes required a trip to Nashville to work with the people doing the computer work. Because of such extra travel, a decision was made to not update land use on the MIADS map. Changes on the MIADS system are not difficult and could have been accomplished but the important thing was to show that MIADS had the capability to

make the desired maps. Ten land use classes are shown in Figure 20 and in Table 7. They are: cropland, grassland, idle land, public and semipublic land, road-side residential, subdivision, woodland, towns, commercial, and water. Woodland and grassland occupy the largest areas, 41% and 32%, respectively.

3. Suitability for Farmland

Figure 21 is an interpretive map showing prime farmland, other important farmland, other land, other land not suited because of wetness, and surface water according to the soils map. Percentage and acreage of these classes are in Table 8. Symbols to fill the gap between the Blount and Loudon county lines were selected by the system from the county boundary map. These voids were created because the lines separating the two counties were not drawn in the same place. Also there were places where the boundaries of the soil survey maps overlapped. These differences could be handled either manually before the data were encoded or by computer after encoding. In this study overlaps were taken out before encoding. This was a mistake. Surveys are generally encoded independently of each other, and it would have been better to handle them that way. However, the method in which overlap was detected and removed is demonstrated in figures presented later. The computer has the capability to detect values that overlay nonzero values in the overlay procedures. These values were given a special symbol so they could be located easily. Since the area of Fort Loudon Lake and other water was taken from the topographic map it did not always agree with that taken from the soil

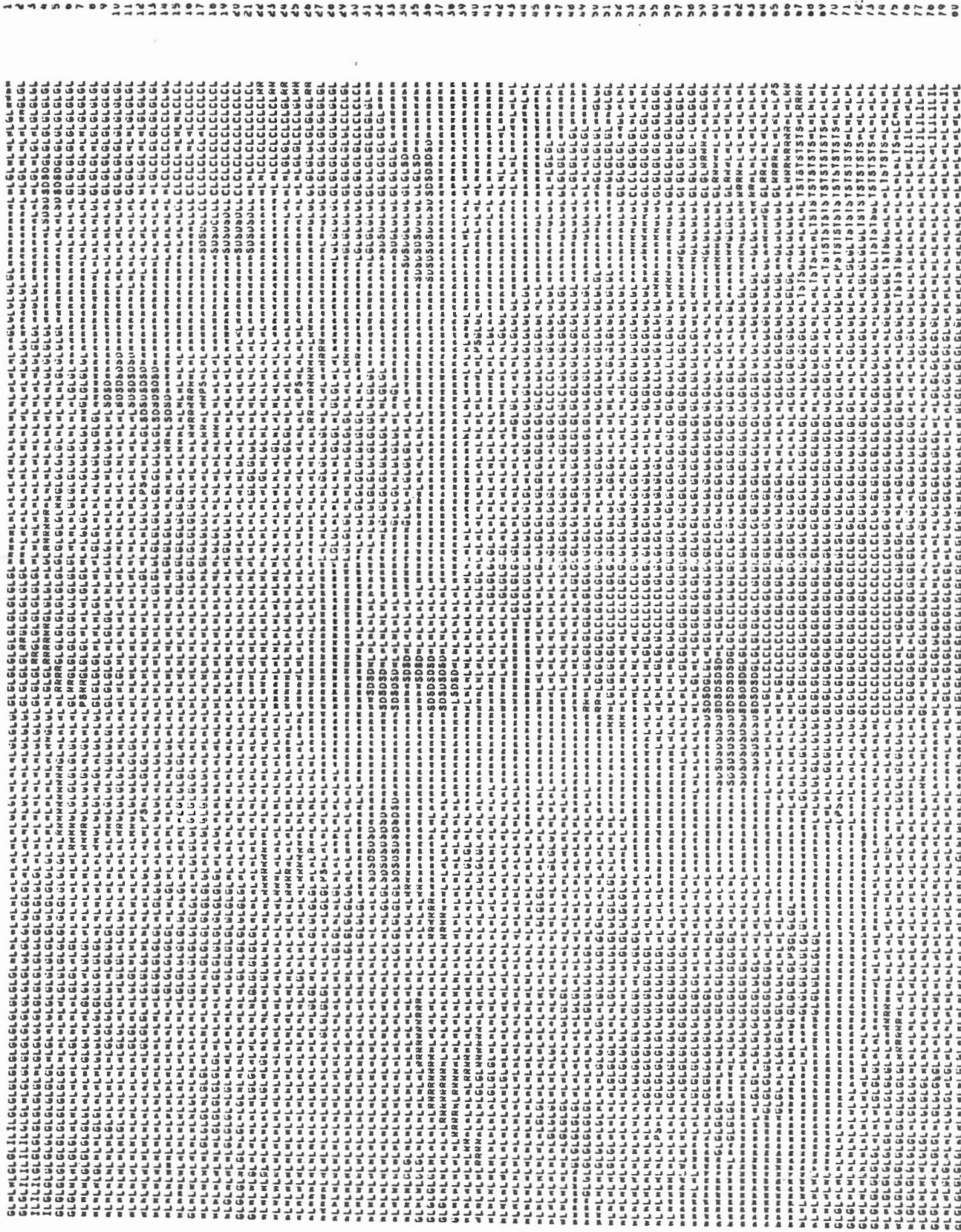


Figure 20. MIADS line printer map of quasi-land use of the Concord study area. The part NW of Fort Loudon Lake is interpreted from a 1975 aerial photograph. The remainder was field checked Spring, 1979.

Table 7. Quasi-land use in the Concord study area (1975) as interpreted from an aerial photograph and topographic map sources—determined from MIADS system output.

Classes	Code	Cells	Hectares	Acres	%
Cropland	CL	176	131	472	2.8
Commercial	CM	1	1	3	0.0
Grassland	GL	2048	2221	5489	32.0
Idle land	IL	21	23	56	0.3
Public-Semi-Public	PS	12	13	32	0.2
Roadside-Residential	RR	152	165	407	2.4
Subdivisions	SD	134	145	359	2.1
Towns	TS	63	68	169	1.0
Woodland	WL	2649	2873	7099	41.3
Water	WW	1144	1241	3066	17.9

Table 8. Suitability for farmland in the Concord study area.
Interpreted from detailed soil map data summarized from
MIADS system output.

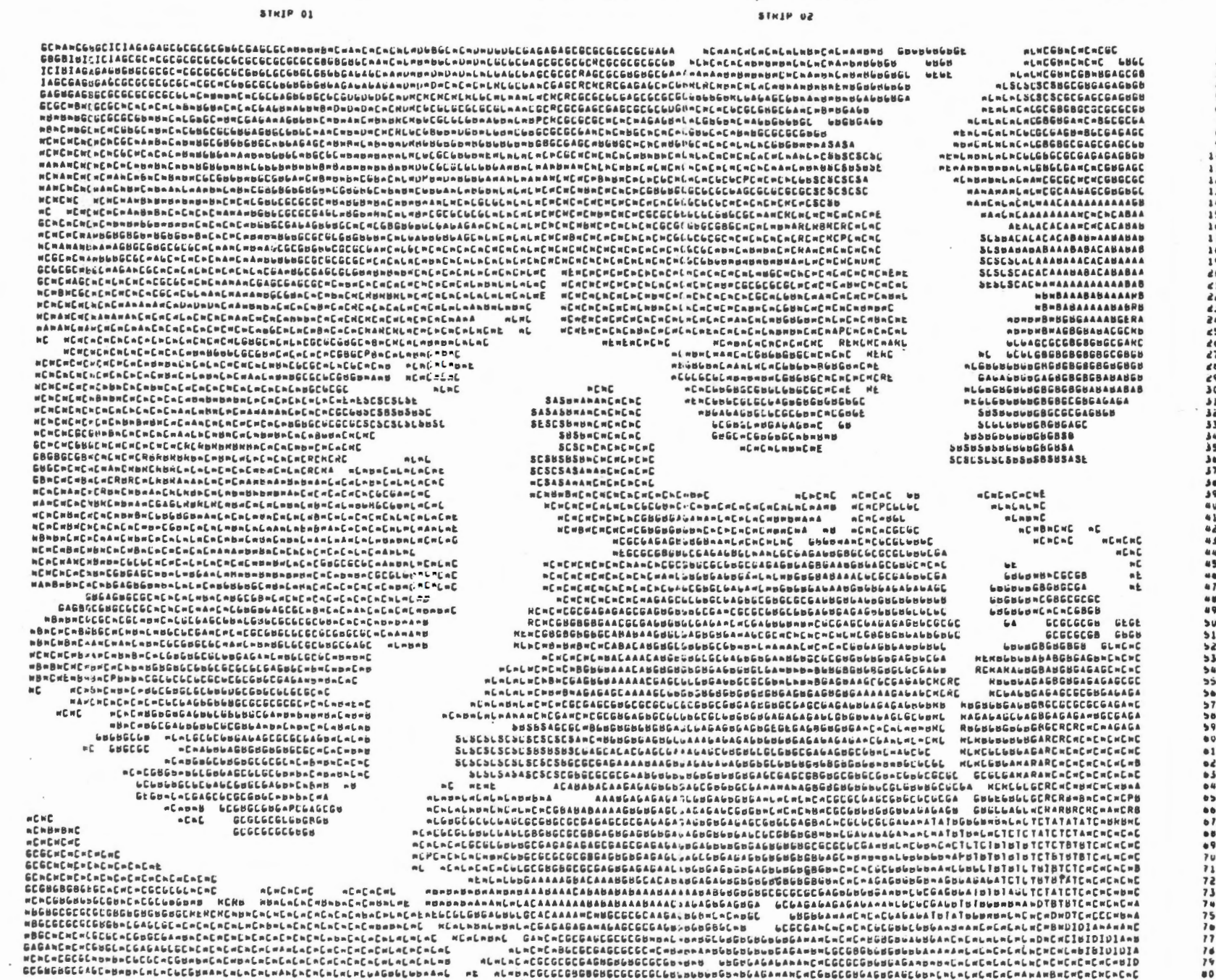
Classes	Code	Cells	Hectares	Acres	%
Blount County*	BL	26	28	70	0.3
Loudon County*	LN	11	12	30	0.2
Prime farmland	11	743	806	1991	11.6
Other important	22	1554	1685	4163	24.2
Other land	33	2934	3182	7863	45.7
Wetness	44	44	48	118	0.7
Water	55	1112	1206	2980	17.3

*Codes from the county boundary map filled the between county voids caused by errors in map registration of the source map.

survey. This caused problems when interpretations from the soil map were combined with land use from the topographic map.

4. Utilization of Important Farmland

A map produced by a matrix between Figures 20 and 21 in the manner of Figure 10 (p. 75) is shown in Figure 22. Area distribution is recorded in Table 9. Some calculations were made on the figures shown in Table 9 to determine how much prime or other important farmland has been developed. Development for the purpose of this map is the construction of towns, subdivisions, houses, or commercial businesses on the land. About 5.4% of the land having prime farmland characteristics is developed and approximately 7% of other important farmland is developed. These percentages differ from those of IMGRID because the IMGRID land use map was updated to show new subdivisions. Since the percentages in Table 9 are based on land mass only, further differences from IMGRID are created. It was done this way because of an error in setting up the matrix (Figure 10). Assignment of the same codes to water and woodlands caused errors on the map. Some problems were avoided by blanking out the water. This required the least amount of time for SCS personnel and provided some contrast to the map. Shading is not available in MIADS. Also, when water was blanked out by the computer the difference between woodlands and water could be identified. Figure 22 shows how land suited for farmland is being used. The codes RA, SA, and TA in Table 9 represent developed prime farmland.



UTILIZATION OF IMPORTANT FARMLAND

USE	SYMBOLS (Prime & Important)	PERCENTAGE	SYMBOLS (Net & Other)	PERCENTAGE
Cropland	AA & AB	2.6	AC & AE	0.7
COMMERCIAL		0.0	CC	0.0
GRASSLAND	GA & GB	23.6	GC, GD & GE	15.1
IDLE LAND	IA & IB	0.2	IC & ID	0.2
PUBLIC	PA & PB	0.1	PC	0.1
ROADSIDE-				
RESIDENTIAL	RA & RB	1.0	RC, RD & RE	1.9
SUB-DIVISION	SA & SB	1.0	SC & SE	1.5
TOWNS	TA & TB	0.8	TC	0.5
WATER		0.0		0.0
WOODLAND	WA & WB	14.0	WC, WD & WE	36.5

Figure 22. MIADS composite of prime and other important farmland and quasi-land use to show uses of different kinds of land for the Concord study area.

Table 9. Suitability for farmland and 1975 quasi-land use for the Concord study area matrixed to show utilization of farmland. Determined from MIADS system output.

Classes	Code	Cells	Hectares	Acres	%
Other land	AC,CC,GC,GD, IC,ID,PC,RC, RD,SC,TC,WC, WD	2912	3158	7804	55.5
Crop on prime land	AA	65	70	174	1.2
Grassland on prime land	GA, IA	425	461	1139	8.1
Woods on prime land	WA	204	221	547	3.9
Other on prime land	RA,SA,TA	40	43	107	0.8
Crop on other important land	AB	72	78	193	1.4
Grassland on other important land	GB,IB	820	890	2198	15.7
Woods on other important land	WB	530	575	1420	10.1
Other on other important land	PB,RB,SB,TB	108	117	289	2.1
Water-land conflicts	AE,GE,RE,SE, WE	67	72	179	1.2
Water*					

*Water blanked out because of error in setting up the matrix.

B. IMGRID

1. Suitability for Farmland by County

The IMGRID maps of suitability for farmland are shown in Figures 23, 24, and 25, and the area distribution for each of the counties is in Tables 10, 11, and 12. The published soil survey on a county format is satisfactory for most areas.

Two errors near the top of the Knox County portion of the study area that were overlooked on Figure 24 were corrected for the printing of Figure 26. Halfway across the top of Figure 24 from left to right are two cells of water that are correct. Another cell located six to the right is in error. Five cells farther to the right and four down is another incorrect cell. The appearance of water in these cells was based on the soil survey. Water would have disappeared if the topographic survey had been used. Similar errors were made on the capability class map. On all other maps where water was based on the topographic maps these cells do not appear as water.

2. Suitability for Farmland—Concord Study Area

If a project covers portions of two or more counties it becomes necessary to combine the counties to obtain soil coverage for the project area. All of the maps for the Concord study area were produced by putting parts of the three counties (Loudon, Knox, and Blount) together. This was done to show that existing files of data from different counties could be put together for a specific project area.



CONCORD QUAD STUDY: LAND ANALYSIS PLANNING & MANAGEMENT DEMONSTRATION
RESOURCE DOCUMENT: SOIL SURVEY U.S.D.A. SOIL CONSERVATION SERVICE,
LONDON, KNOX, AND BLOUNT COUNTIES, TENNESSEE

CONCORD QUADRANGLE, TENNESSEE
SOUTHEASTERN PORTION 5 MINUTES PER SIDE

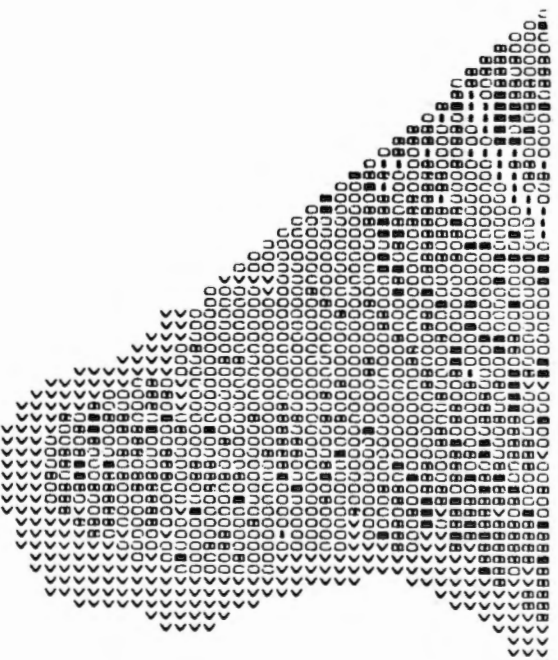
LEGEND

0 = NO DATA
1 = PRIME FARMLAND
2 = ADDITIONAL IMPORTANT FARMLAND
3 = OTHER LAND
4 = WILDERNESS LIMITATION
5 = WATER

FREQUENCY

LEVELS	1	2	3	4	5
241	632	1420	5	441	

Figure 23. IMGRID line printer map of suitability for farmland for the Loudon County portion of the Concord study area.



CONCORD QUAD STUDY, LAND ANALYSIS PLANNING & MANAGEMENT DEMONSTRATION
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 LOUDON, KNOX, AND GROUT COUNTIES, TENNESSEE

CONCORD QUADRANGLE, TENNESSEE SOUTHEASTERN PORTION 5 MINUTES PER SIDE

LEGEND
 0 = NO DATA
 1 = PRIMARY FARMLAND
 2 = ADDITIONAL IMPORTANT FARMLAND
 3 = UNFARMED LAND
 4 = WETLANDS
 5 = WETLANDS

LEVELS
 1 = 1
 2 = 2
 3 = 3
 4 = 4
 5 = 5
 FREQUENCY
 46 234 637 29 253

Figure 24. IMGRID line printer map of suitability for farmland for the Knox County portion of the Concord study area.

CONCORD QUADRANGLE, TENNESSEE
SOUTHEASTERN PORTION 5 MINUTES PER SIDE

FREQUENCY	LEVELS
411	1
611	2
874	3
11	4
432	5

Figure 25. IMGRID time printer map of suitability for farmland for the Blount County portion of the Concord study area.

Table 10. Loudon County contribution to suitability for farmland of the Concord study area. Determined from IMGRID system output.

Classes	Cells	Hectares	Acres	%
Prime farmland	241	261	646	3.8
Other important	632	685	1694	9.8
Other land	1420	1540	3806	22.2
Wetness	5	5	13	0.1
Water	441	478	1182	6.9
Other counties	3661	3971	9812	57.2

Table 11. Knox County contribution to suitability for farmland of the Concord study area. Determined from IMGRID system output.

Classes	Cells	Hectares	Acres	%
Prime farmland	88	95	236	1.4
Other important	234	254	627	3.6
Other land	637	691	1707	10.0
Wetness	29	31	78	0.5
Water	253	278	687	3.9
Other counties	5159	5595	13826	80.6

Table 12. Blount County contribution to suitability for farmland of the Concord study area. Determined from IMGRID system output.

Classes	Cells	Hectares	Acres	%
Prime farmland	411	446	1102	6.5
Other important	681	738	1825	10.6
Other land	874	948	2342	13.6
Wetness	11	12	30	0.2
Water	432	469	1158	6.8
Other counties	3991	4329	10696	62.3

The overlay keyword of IMGRID was used to put Figures 23, 24, and 25 together. The results of this overlay are shown in Figure 26. Area distribution is in Table 13. The suitability for farmland map was produced to show that interpretive maps for parts of several counties could be joined together by computer to provide coverage for a particular study area. It also shows the suitability for farmland. Excepting the void between the Blount and Loudon County lines this IMGRID map is similar to the one produced with MIADS (Figure 21, p. 95). This void was filled with codes from the boundary map in MIADS and the colon was used on the IMGRID map. Another difference is that the overprinting capability of IMGRID makes the maps much easier to read than do the codes used in the MIADS system. That this map can be combined with other collected data is demonstrated in Figure 11 (p. 76) which shows a matrix between suitability for farmland and land use.

3. Depth to Bedrock—Concord Study Area

A depth to bedrock map was produced by combining single factor county maps into coverage for the study area. Single factor maps rather than the original data were used because the same symbols represented different soils from one county to another. For example, Ba in Blount County represents Barbourville fine sandy loam, a soil that is thicker than 1.8 m (6 ft) to bedrock, while in Knox County Ba is the symbol for Bland silt loam, a soil that is only 0.6-1.2 m (2-4 ft) to bedrock. Figure 27 is an overlay of depth to bedrock for the Concord study area. The area distribution is recorded in

Table 13. Suitability for farmland in the Concord study area.
 Interpreted from detailed soil map data summarized from
 IMGRID system output.

Classes	Cells	Hectares	Acres	%
Prime farmland	735	797	1970	11.5
Other important farmland	1545	1676	4141	24.1
Other land	2917	3164	7818	45.6
Wetness	45	48	120	0.7
Water	1145	1242	3069	17.9
No data	13	14	35	0.2



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CONCORD QUADRANGLE, TENNESSEE
 SOUTHEASTERN PORTION 5 MINUTES PER SIDE

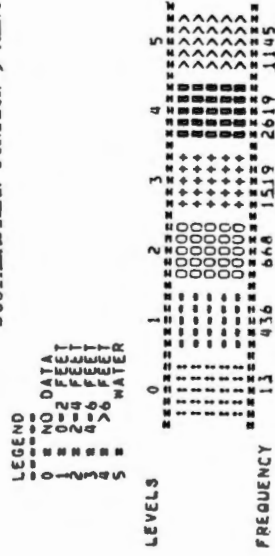


Figure 27. IMGRID line printer map of depth to bedrock for the Concord study area.

Table 14. The map showing thickness above bedrock furnishes information for other kinds of analyses such as interpretations for a sanitary landfill or for a residential development requiring the use of septic tanks. Both of these uses need depths of 1.8 m (6 ft) or more to bedrock. Several different kinds of maps were produced by IMGRID to show several ways that data can be used after they are encoded into a computer assisted system.

Because the MIADS suitability for farmland map demonstrated that the system could be used to produce interpretive maps, there was no need to produce a depth to bedrock map with MIADS.

4. Land Capability Classes—Concord Study Area

The land capability class map was produced to show the location and to determine the amount of each class of land. This map is important because land capability classes relate to agricultural uses of the land. One problem that had to be resolved was due mainly to the age of the Knox County survey. Knox County used a system with five suitability classes rather than the eight classes used in the land capability classification. This problem was solved by going back to the soil mapping units of Knox County and fitting each one into a land capability class. The map of land capability classes is shown in Figure 28 and the area distribution is in Table 15.

5. Sanitary Landfill—Concord Study Area

The sanitary landfill interpretations (Figure 29) are becoming more important as large volumes of waste are being generated daily

Table 14. Depth to bedrock in the Concord study area. Interpreted from soil map data using the IMGRID system.

Classes	Cells	Hectares	Acres	%
0-2 ft. (0-0.6 m)	436	473	1169	6.8
2-4 ft. (0.6-1.2 m)	668	746	1844	10.7
4-6 ft. (1.2-1.8 m)	1519	1647	4071	23.6
>6 ft. (>1.8 m)	2619	2840	7019	40.8
Water	1145	1242	3069	17.9
No data	13	14	35	0.2



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 LOUDON, KNOX, AND BLOUNT COUNTIES, TENNESSEE

CONCORD QUADRANGLE, TENNESSEE
 SOUTHEASTERN PORTION 5 MINUTES PER SIDE

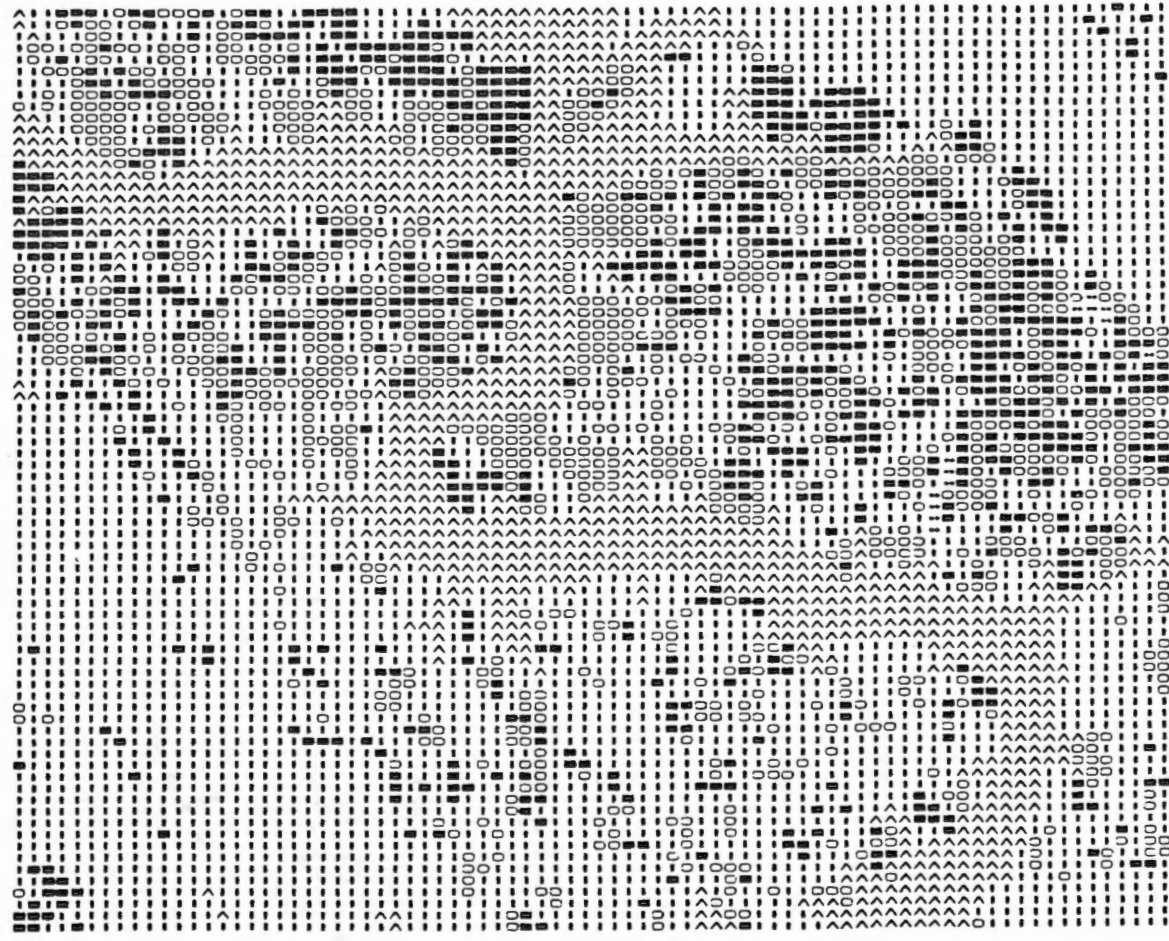
LEGEND
 0 = NO DATA
 1 = CLASS I
 2 = CLASS II
 3 = CLASS III
 4 = CLASS IV
 5 = CLASS V
 6 = CLASS VI
 7 = WATER

LEVELS	FREQUENCY							
	0	1	2	3	4	5	6	7
0	1111	0000	0000	0000	0000	0000	0000	0000
1	1111	0000	0000	0000	0000	0000	0000	0000
2	1111	0000	0000	0000	0000	0000	0000	0000
3	1111	0000	0000	0000	0000	0000	0000	0000
4	1111	0000	0000	0000	0000	0000	0000	0000
5	1111	0000	0000	0000	0000	0000	0000	0000
6	1111	0000	0000	0000	0000	0000	0000	0000
7	1111	0000	0000	0000	0000	0000	0000	0000
8	1111	0000	0000	0000	0000	0000	0000	0000
9	1111	0000	0000	0000	0000	0000	0000	0000
10	1111	0000	0000	0000	0000	0000	0000	0000
11	1111	0000	0000	0000	0000	0000	0000	0000
12	1111	0000	0000	0000	0000	0000	0000	0000
13	1111	0000	0000	0000	0000	0000	0000	0000
14	1111	0000	0000	0000	0000	0000	0000	0000
15	1111	0000	0000	0000	0000	0000	0000	0000
16	1111	0000	0000	0000	0000	0000	0000	0000
17	1111	0000	0000	0000	0000	0000	0000	0000
18	1111	0000	0000	0000	0000	0000	0000	0000
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20	1111	0000	0000	0000	0000	0000	0000	0000
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24	1111	0000	0000	0000	0000	0000	0000	0000
25	1111	0000	0000	0000	0000	0000	0000	0000
26	1111	0000	0000	0000	0000	0000	0000	0000
27	1111	0000	0000	0000	0000	0000	0000	0000
28	1111	0000	0000	0000	0000	0000	0000	0000
29	1111	0000	0000	0000	0000	0000	0000	0000
30	1111	0000	0000	0000	0000	0000	0000	0000
31	1111	0000	0000	0000	0000	0000	0000	0000
32	1111	0000	0000	0000	0000	0000	0000	0000
33	1111	0000	0000	0000	0000	0000	0000	0000
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35	1111	0000	0000	0000	0000	0000	0000	0000
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37	1111	0000	0000	0000	0000	0000	0000	0000
38	1111	0000	0000	0000	0000	0000	0000	0000
39	1111	0000	0000	0000	0000	0000	0000	0000
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43	1111	0000	0000	0000	0000	0000	0000	0000
44	1111	0000	0000	0000	0000	0000	0000	0000
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46	1111	0000	0000	0000	0000	0000	0000	0000
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66	1111	0000	0000	0000	0000	0000	0000	0000
67	1111	0000	0000	0000	0000	0000	0000	0000
68	1111	0000	0000	0000	0000	0000	0000	0000
69	1111	0000	0000	0000	0000	0000	0000	0000
70	1111	0000	0000	0000	0000	0000	0000	0000
71	1111	0000	0000	0000	0000	0000	0000	0000
72	1111	0000	0000	0000	0000	0000	0000	0000
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77	1111	0000	0000	0000	0000	0000	0000	0000
78	1111	0000	0000	0000	0000	0000	0000	0000
79	1111	0000	0000	0000	0000	0000	0000	0000
80	1111	0000	0000	0000	0000	0000	0000	0000
81	1111	0000	0000	0000	0000	0000	0000	0000
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95	1111	0000	0000	0000	0000	0000	0000	0000
96	1111	0000	0000	0000	0000	0000	0000	0000
97	1111	0000	0000	0000	0000	0000	0000	0000
98	1111	0000	0000	0000	0000	0000	0000	0000
99	1111	0000	0000	0000	0000	0000	0000	0000
100	1111	0000	0000	0000	0000	0000	0000	0000

Figure 28. IMGRID line printer map of land capability classes for the Concord study area.

Table 15. Land capability classes in the Concord study area.
Interpreted from soil map data using the IMGRID system.

Class	Cells	Hectares	Acres	%
I	357	387	957	5.5
II	533	587	1428	8.3
III	1463	1586	3920	22.3
IV	1850	2006	4958	28.9
VI	462	501	1238	7.2
VII	597	647	1600	9.2
Water	1145	1242	3069	17.9
No data	13	14	35	0.2



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CONCORD QUADRANGLE, TENNESSEE
SOUTHEASTERN PORTION 5 MINUTES PER SIDE

LEGEND
0 = DATA
1 = SIGHT
2 = MODERATE
3 = SEVERE
4 = MAJOR

LEVELS
0 1 2 3 4
===== 0000 0000 0000 0000 0000
1111 0000 0000 0000 0000
1111 0000 0000 0000 0000
1111 0000 0000 0000 0000
===== 13 887 1040 3275 1145
FREQUENCY

Figure 29. IMGRID line printer map of limitations for sanitary landfill for the Concord study area.

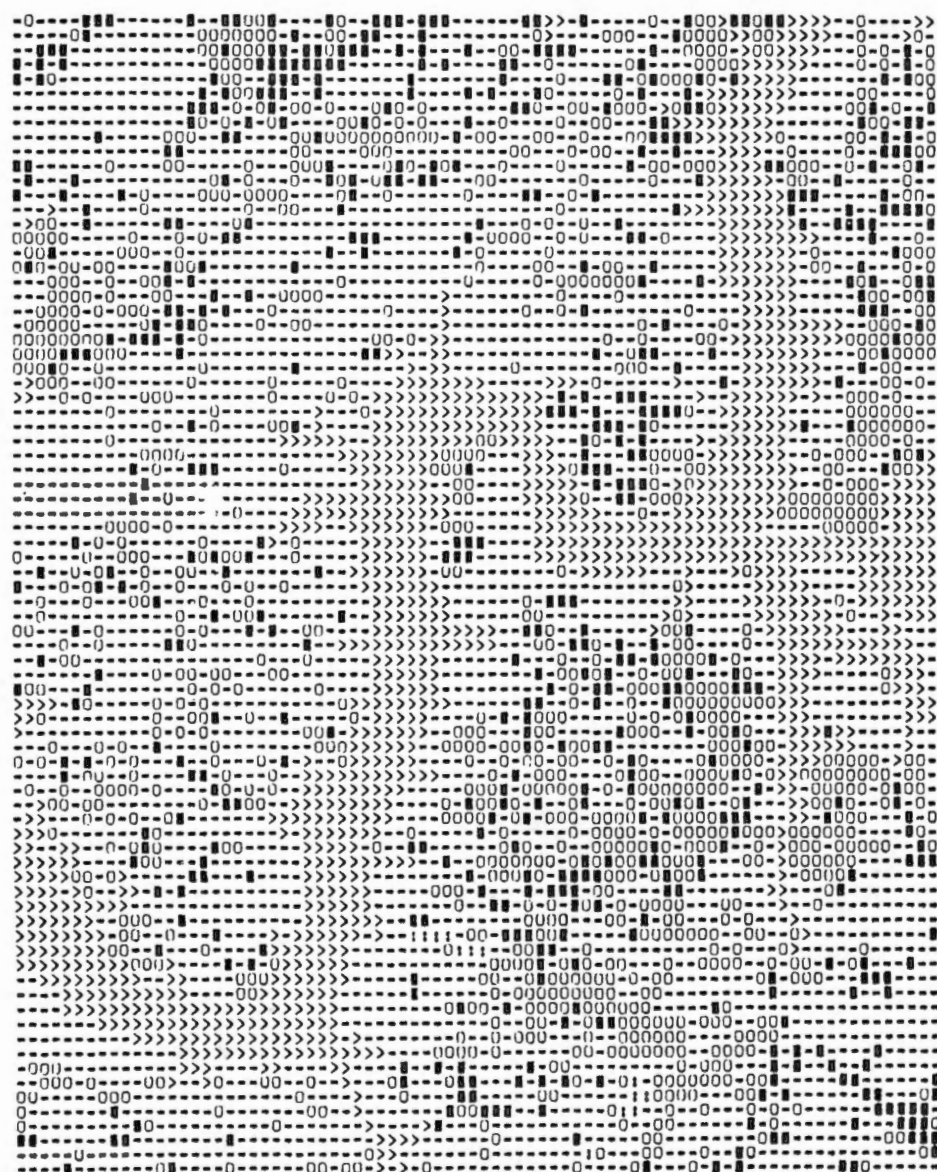
and because people are becoming more conscious of the environmental effects caused by disposal of such waste. Larger cities have the worst problem finding landfill sites because of the high concentration of people, scarcity of land, and because nobody wants a landfill in the community. The area distribution for Figure 29 is recorded in Table 16. Only 13.8% of the area was considered to have soils best suited for a landfill from a physical standpoint. The amount of land suited for a landfill decreases as more restrictions are placed on the criteria. The general criteria used in rating a soil for a landfill site are listed in Appendix A. Other factors besides soils must be considered when selecting a landfill site. Therefore, an interpretation from soils should be combined with other data to create a model that deals with the physical constraints, transportation problems, and the environmental considerations for selecting a landfill.

6. Erosion Potential—Concord Study Area

Figure 30 shows the location of soils that have a high potential for eroding if the cover is removed for construction or if cultivation is performed. The Loudon County soil survey uses the terms slight, moderate, and severe to identify existing erosion. However, that differs from this study where the terms slight, moderate, and severe were used to identify potential for erosion if vegetative cover is removed. Placement of soil mapping units into the classes of erosion potential had to be done on a county by county basis because the mapping unit names were not identical in all the

Table 16. Limitations for sanitary landfill in the Concord study area. Interpreted from soil map data using the IMGRID system.

Classes	Cells	Hectares	Acres	%
Slight	887	942	2377	13.8
Moderate	1080	1171	2894	16.9
Severe	3275	3552	8777	51.2
Water	1145	1242	3069	17.9
No data	13	14	35	0.2



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CONCORD QUADRANGLE, TENNESSEE
 SOUTHEASTERN PORTION 5 MINUTES PER SIDE

LEGEND
 0 = NO DATA
 1 = SLIGHT
 2 = MODERATE
 3 = SEVERE
 4 = WATER

LEVELS	0	1	2	3	4
	11111	00000	00000	00000	00000
	11111	00000	00000	00000	00000
	11111	00000	00000	00000	00000
	11111	00000	00000	00000	00000
	11111	00000	00000	00000	00000
FREQUENCY	13	581	1182	1479	1145

Figure 30. IMGRID line printer map of erosion potential for the Concord study area.

counties. The criteria for making all interpretations are listed in Appendix A. Table 17 gives the area distribution for soils with different erosion potentials. Only 9.1% of the area had slight potential for erosion.

7. Slope—Concord Study Area

The slope map (Figure 31) was produced by dividing the slopes of soil mapping units into five classes. The classes are identified in Appendix A (Criteria for Rating Soil Mapping Units). Table 18 shows that about 43% of the study area has slopes of less than 12%. Land with slopes of less than 12% can be used safely for more purposes and with less management and expense than steeper land. Slope can be used with other soil characteristics to determine if a site is suitable for a particular use. For example, slope has been used manually as one factor in determining suitability for a sanitary landfill or prime farmland. Soil mapping units with slopes of 12% and less were rated as having slight limitations for sanitary landfill if all other conditions were met. Soils with slopes of 5% or less were rated as prime farmland when other conditions were met.

8. Roads and Streams—Concord Study Area

Figure 32 shows roads and perennial streams, features which are used in the development of the landfill model. Errors made while encoding these data are explained in Chapter V under preparation of information for encoding. These errors were not corrected because: (1) they made little difference in the final maps, and (2) they were

Table 17. Soil erosion potential in the Concord study area.
Interpreted from soil map data using the IMGRID system.

Classes	Cells	Hectares	Acres	%
Slight	581	630	1557	9.1
Moderate	1182	1282	3168	18.5
Severe	3479	3773	9324	54.3
Water	1145	1242	3069	17.9
No data	13	14	35	0.2

Table 18. Slope gradient in the Concord study area. Interpreted from soil map data using the IMGRID system.

Classes	Cells	Hectares	Acres	%
0-2%	250	271	670	3.9
2-5%	591	641	1584	9.2
5-12%	1909	2070	5116	29.9
12-25%	1385	1502	3712	21.6
>25%	1107	1200	2967	17.3
Water	1145	1460	3609	17.3
No data	13	14	35	0.2

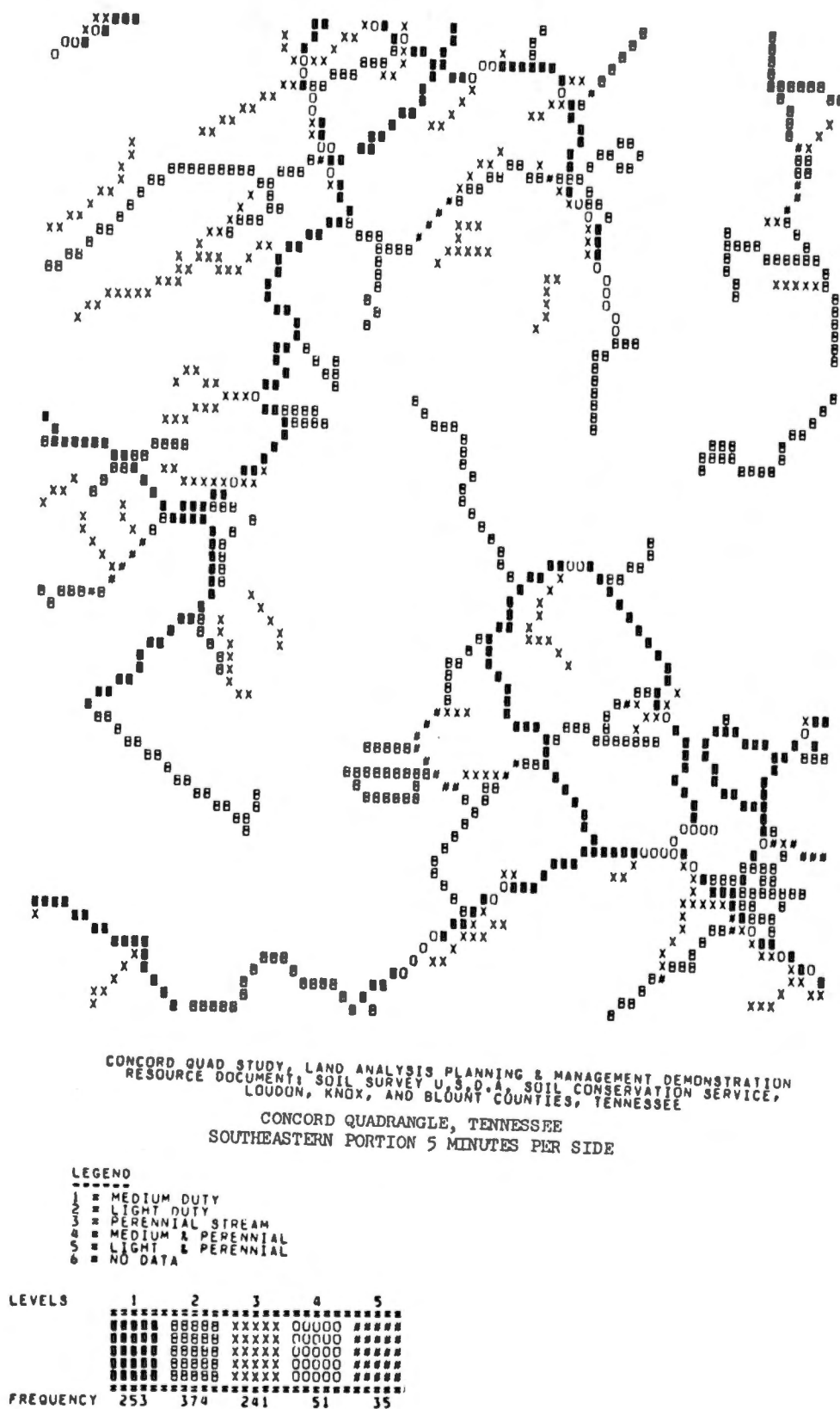


Figure 32. IMGRID line printer map of selected roads and streams for the Concord study area.

discovered after the maps had been photographically reproduced for the manuscript. A few areas were affected by leaving three streams off the roads and streams maps. Correction of these omissions would show that eight cells now shown as suitable for sanitary landfill are within three cells of water. However, after clumping to eliminate areas too small for landfill consideration these eight cells were eliminated from the suitable class. Consequently, the errors made in the encoding process affected one of the maps in the model but because of clumping and the location of the omitted streams and road did not materially affect the final map. Road and stream data are combined with other data such as land use to produce maps showing potential landfill sites and their proximity to roads and streams. Fort Loudon Lake was taken from the land use file and combined with streams from Figure 32 to show waters of the study area.

9. Land Use—IMGRID

A map of land use in August 1979 was produced using IMGRID. Ten land use classes are shown in Figure 33 and the area distribution for these classes is in Table 19. The classes are defined in the methods and procedures on page 68. The results would have been similar for both systems, if land use had been determined at the same time. Two reasons why the entire MIADS map for land use was not updated to 1979 were: (1) a land use comparison of Figures 20 (page 91) and 33 for the area northwest of the main channel of Fort Loudon Lake shows that some grassland in 1975 had been changed to subdivision by 1979; (2) more time and expense for SCS personnel

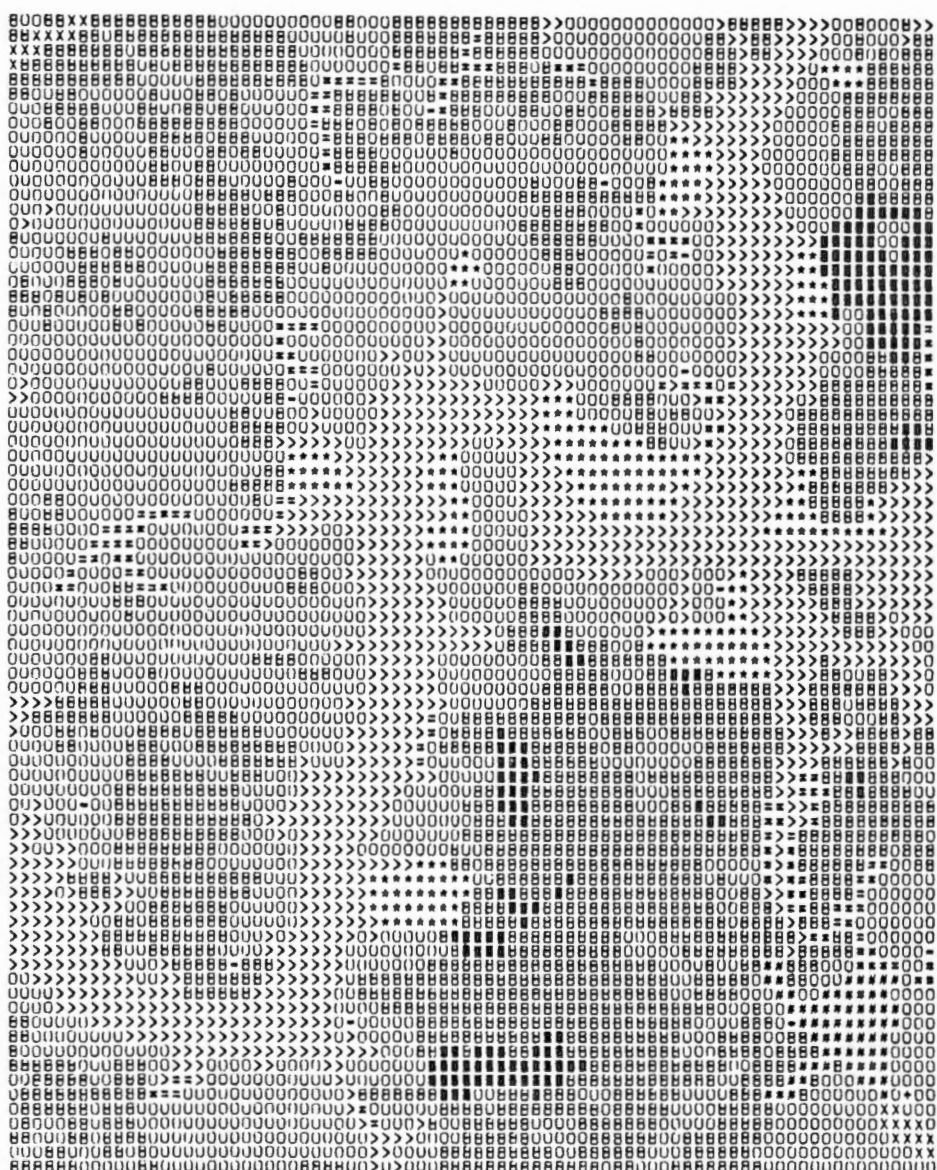


Figure 33. IMGRID line printer map of 1979 quasi-land use, as tabulated by the author, for the Concord study area.

Table 19. Quasi-land use in the Concord study area (August 1979).
Summarized with the IMGRID system from maps produced
using aerial photographs and field observations.

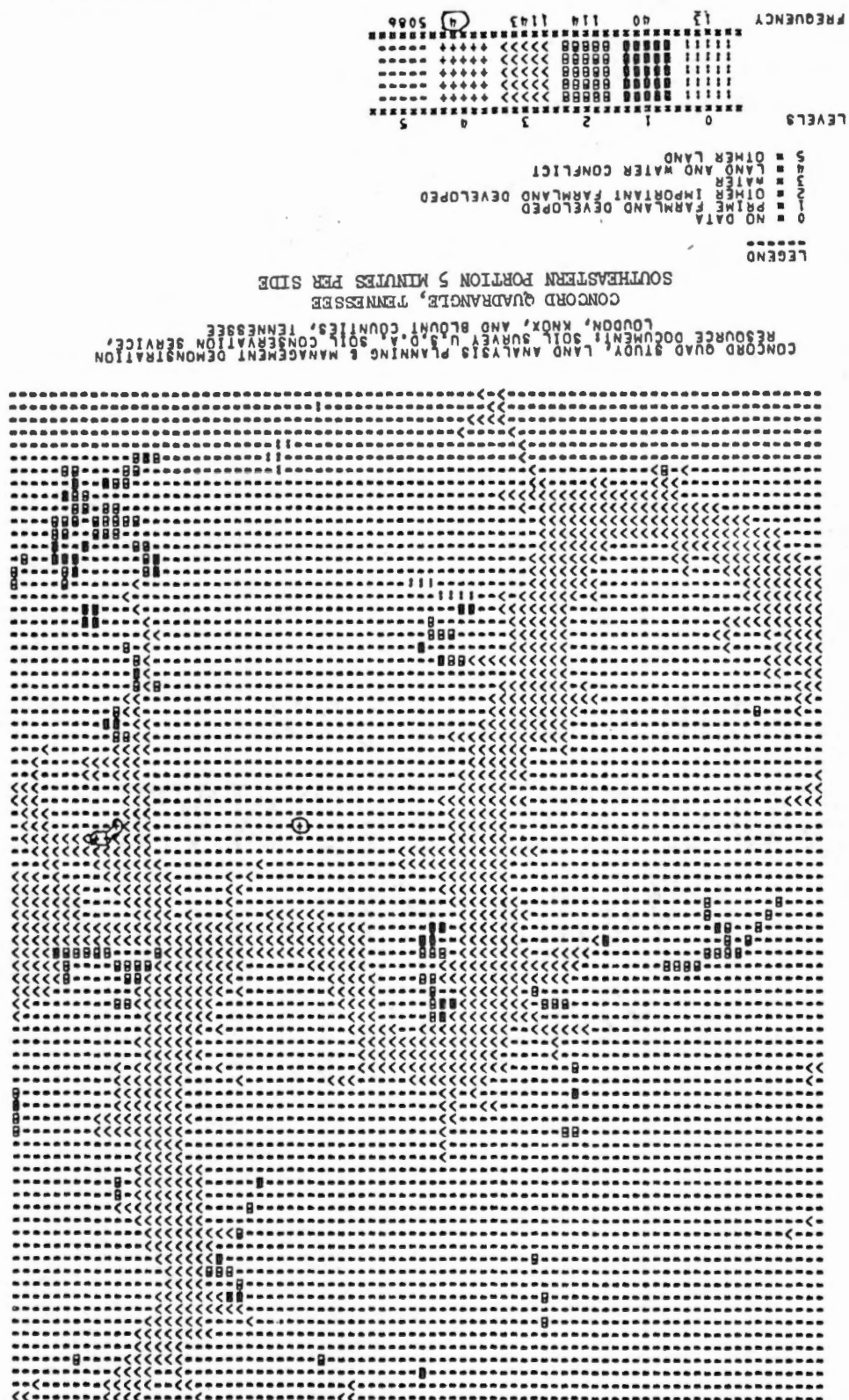
Classes	Cells	Hectares	Acres	%
Cropland	175	190	469	2.7
Grassland	1988	2156	5328	31.1
Woodland	2590	2809	6941	40.5
Roadside-residential	152	165	407	2.4
Commercial	1	1	3	0.0
Public and semi-public	12	12	32	0.2
Idle land	22	24	59	0.3
Subdivisions	250	271	670	3.9
Towns	65	70	174	1.0
Water	1145	1242	3069	17.9

would have been required to make the changes on the MIADS land use map. Another difference was in the amount of water shown on the two maps. This difference could have been due to coding techniques, errors, or the placement of the grid. The main difference between the land use maps produced by MIADS and IMGRID is that part of the land use for MIADS was interpreted from a 1975 aerial photograph with some field checking, while land use for IMGRID was for 1979 and included changes observed by more thorough field checking. The IMGRID map shows patterns much better than the MIADS map. This improvement is due to the overprinting capabilities of the IMGRID system. Gray level maps are possible and patterns can be seen easily. The land use map showing development (Figure 33) was used in the construction of the landfill model. The difference in subdivision area of 145 hectares in Table 7 (page 94) and 271 hectares in Table 19 is due to an update of the land use map to include newly constructed subdivisions.

10. Combination of Land Use with Other Data—Concord Study Area

a. Farmland lost to development. Figures 34 and 35 show where prime farmland has been developed as towns, subdivisions, or commercial development. Figure 35 was produced by a matrix between the 1979 land use (Figure 33) and suitability for farmland (Figure 26, page 107). Interpretations were made as shown in Figure 12 (page 77). Some land that qualifies for prime farmland has been used for subdivisions, towns, and other uses. Differences between Figures 34 and 35 are several. After Figure 34 was produced the

Figure 34. IMGRID composite of suitability for farmland and quasi-land use as interpreted from a 1975 aerial photograph to show farmland lost to development and some land and water conflicts for the Concord study area.





CONCORD QUADRANGLE, TENNESSEE
SOUTHEASTERN PORTION 5 MINUTES PER SIDE

LEGEND

0 = NO DATA
1 = PRIME FARMLAND DEVELOPED
2 = OTHER IMPORTANT FARMLAND DEVELOPED
3 = WATER
4 = LAND AND WATER CONFLICT
5 = OTHER LAND

LEVELS	0	1	2	3	4	5
FREQUENCY	13	53	157	1145	0	5052

Figure 35. Modified IMGRID composite of suitability for farm and development and 1979 quasi-land use to show farmland lost to development for the Concord study area.

land use was updated to 1979 as shown in Figure 35. Also, Figure 34 shows cells that have land water conflicts caused by inconsistency of the different source documents that the data were extracted from. The soil interpretations were taken from the soil survey. Land use was taken from the topographic map. For some cells the land and water overlapped. This problem was cleared up by changing water on the soil map to correspond to that on the topographic map. Difference in the amount of water shown on the two maps was small. Normally one would expect the soil survey to show more water because of some small ponds on the photo base, but not on the topographic map, being captured in the encoding process. This accounts for some of the difference, but the water level of the lake when photographed and distortion in the photograph caused lake boundaries to differ from those on the topographic map. Another cause may have been centering of the grid to allow even distribution over distorted photographs. The area distributions for Figures 34 and 35 are in Tables 20 and 21, respectively.

b. Utilization of farmland. Figure 36 was produced by a matrix between 1979 land use and suitability for farmland. Interpretations are shown in Figure 11 (page 76). This map shows how prime farmland and additional important farmland were being used in 1979. The utilization of important farmland map was also produced by MIADS Figure 22 (page 98) and Table 9 (page 99). The results of combinations in Table 9 and Table 22 differ because MIADS' area was calculated on the land area and IMGRID was based on total area. Other differences were due to use of 1975 land use for MIADS and

Table 20. Loss of prime and other important farmland to development in the Concord study area. Summarized by the IMGRID system from maps produced from aerial photographs.

Classes	Cells	Hectares	Acres	%
Prime farmland lost	40	43	107	0.6
Other important farmland lost	114	124	306	1.8
Other land	5086	5516	13630	79.5
Land and water conflict	4	4	11	0.1
Water	1143	1240	3063	17.8
No data	13	14	35	0.2

Table 21. Loss of prime and other important farmland to development in the Concord study area after updating the quasi-land use to 1979 conditions. Maps summarized using the IMGRID system.

Classes	Cells	Hectares	Acres	%
Prime farmland lost	53	57	142	0.8
Other important farmland lost	157	170	421	2.5
Other land	5032	5457	13485	78.6
Land and water conflict	0	0	0	0.0
Water	1145	1242	3069	17.9
No data	13	14	35	0.2

CONCORD QUADRANGLE, TENNESSEE
SOUTHEASTERN PORTION 5 MINUTES PER SIDE

```

LEGEND
0 = NO DATA
1 = LAND NOT SUITABLE FOR FARMLAND
2 = CROPLAND UN PRIME FARMLAND
3 = GRASSLAND AND IDLE LAND ON PRIME FARMLAND
4 = WOODLAND ON PRIME FARMLAND
5 = OTHER LAND USES ON PRIME FARMLAND
6 = CROPLAND ON OTHER IMPORTANT FARMLAND
7 = GRASSLAND AND IDLE LAND ON OTHER IMPORTANT FARMLAND
8 = WOODLAND ON OTHER IMPORTANT FARMLAND
9 = OTHER LAND USES ON OTHER IMPORTANT FARMLAND
10 = WATER

LEVELS      0      1      2      3      4      5      6      7      8      9      10
11111 ----- 11111 88888 ##### 00000 XXXXX ***** +++++ ===== >>>>
11111 ----- 11111 88888 ##### 00000 XXXXX ***** +++++ ===== >>>>
11111 ----- 11111 88888 ##### 00000 XXXXX ***** +++++ ===== >>>>
11111 ----- 11111 88888 ##### 00000 XXXXX ***** +++++ ===== >>>>
11111 ----- 11111 88888 ##### 00000 XXXXX ***** +++++ ===== >>>>
----- 11111 88888 ##### 00000 XXXXX ***** +++++ ===== >>>>
----- 11111 88888 ##### 00000 XXXXX ***** +++++ ===== >>>>
----- 11111 88888 ##### 00000 XXXXX ***** +++++ ===== >>>>
----- 11111 88888 ##### 00000 XXXXX ***** +++++ ===== >>>>
FREQUENCY   13    2962     64    414    204     53     70    797    521    157    1145

```

Figure 36. IMGRID composite of suitability for farmland and 1979 quasi-land use to show uses of different kinds of land for the Concord study area.

Table 22. Utilization of Concord study area farmland in 1979.
Determined by a matrix between suitability for farmland
interpretations and 1979 quasi-land use. Analysis and
summary using the IMGRID system.

	Cells	Hectares	Acres	%
Not suited for farming	2962	3212	7938	46.3
Cropland on prime farmland	64	69	171	1.0
Grassland on prime farmland	414	339	1109	6.5
Woodland on prime farmland	204	221	547	3.2
Other users on prime farmland	53	57	142	0.8
Cropland on other important farmland	70	76	188	1.1
Grassland on other important farmland	797	864	2136	12.5
Woodland on other important farmland	521	565	1396	8.1
Other uses on other important farmland	157	170	421	2.4
Water	1145	1242	3069	17.9
No data	13	14	35	0.2

1979 land use for IMGRID. Values from the two methods would compare more closely if calculations for MIADS were based on total area. For example, woodland on prime farmland has the same number of occurrences, but the percentage is 3.9 for MIADS and only 3.2 for IMGRID. Other differences are the amount of water blanked out on the MIADS map and discrepancies caused by taking data from two source maps. The percentages were similar for both systems when figured on total area. Only 0.8% of the total land has development on land suitable for prime farmland. This means that about 7% of the land suitable for prime farmland has some type of development. About 10% of the other important farmland has been developed.

Figure 36 shows land that may not be recovered for farming because of uses such as residential and commercial developments. Much prime farmland now in pasture or woodland can easily be put into food crop production when needed.

c. Potential landfill sites. Figure 37 was produced by a matrix between 1979 land use and the sanitary landfill interpretation from soils to show undeveloped sites that are suited for landfills. Table 23 shows that 54.9% of the area is either not suited for a landfill or conflicts with some type of development. Only 27% have slight and moderate limitations and are undeveloped. This simple kind of analysis is good enough for some decisions, but most problems, especially something so sensitive as the location of a sanitary landfill, require more information.

CONCORD QUADRANGLE, TENNESSEE
SOUTHEASTERN PORTION 5 MINUTES PER SIDE

0 = NO DATA
1 = SITES WITH SLIGHT OR NO LIMITATIONS
2 = SITES WITH MODERATE LIMITATIONS
3 = SITES NOT SUITABLE OR DEVELOPED AREAS
4 = LAND AND WATER CONFLICT
5 = WATER

LEVELS	0	1	2	3	4	5
1 1 1 1	0000	0000	0000	0000	0000	0000
1 1 1 1	0000	0000	0000	0000	0000	0000
1 1 1 1	0000	0000	0000	0000	0000	0000
1 1 1 1	0000	0000	0000	0000	0000	0000
1 1 1 1	0000	0000	0000	0000	0000	0000
1 1 1 1	0000	0000	0000	0000	0000	0000
FREQUENCY	13	784	950	350	0	1145

Figure 37. IMGRID composite of sanitary landfill interpretation and 1979 quasi-land use showing suitable landfill sites that do not conflict with development for the Concord study area.

Table 23. Limitations for landfill sites in the Concord study area. Determined by a matrix between sanitary landfill limitations and 1979 quasi-land use. Analysis and summary using the IMGRID system.

Classes	Cells	Hectares	Acres	%
Slight	784	850	2101	12.2
Moderate	950	1030	2546	14.8
Severe or developed	3508	3804	9401	54.9
Land and water conflict	0	0	0	0
Water	1145	1242	3069	17.9
No data	13	14	35	0.2

The IMGRID spatial analysis system has capabilities for handling more complicated analyses than MIADS. One capability of IMGRID will be demonstrated in the next series of maps and tables.

11. Landfill Model—Concord Study Area

The components of the landfill model are flowcharted in Figure 38. Four of the things that should be considered are: (a) limitations of soils, (b) distance from roads, (c) distance from development, and (d) nearness to water.

a. Search from roads. One of the first priorities in locating a sanitary landfill would be an adequate transportation route to the site. There is no special rule as to how close a site should be to a road, but for this study we are concerned only with those sites that are within five (1.08 hectare) cells (approximately 500 m) of roads. A search was performed to identify such cells. The results are in Figure 39 and the area distribution is recorded in Table 24. The land and water within 5 cells of roads comprise 67.9% and if the cell that the road occurs in is included, the percentage is 79.1. For this information to be useful it must be combined with the sanitary landfill interpretation from soils to show sites that meet the other specified criteria.

b. Landfill sites close to roads. In addition to availability of transportation, a factor to be considered when locating a sanitary landfill is suitability of soils for landfill. The sanitary landfill interpretation was combined with the search from roads to show

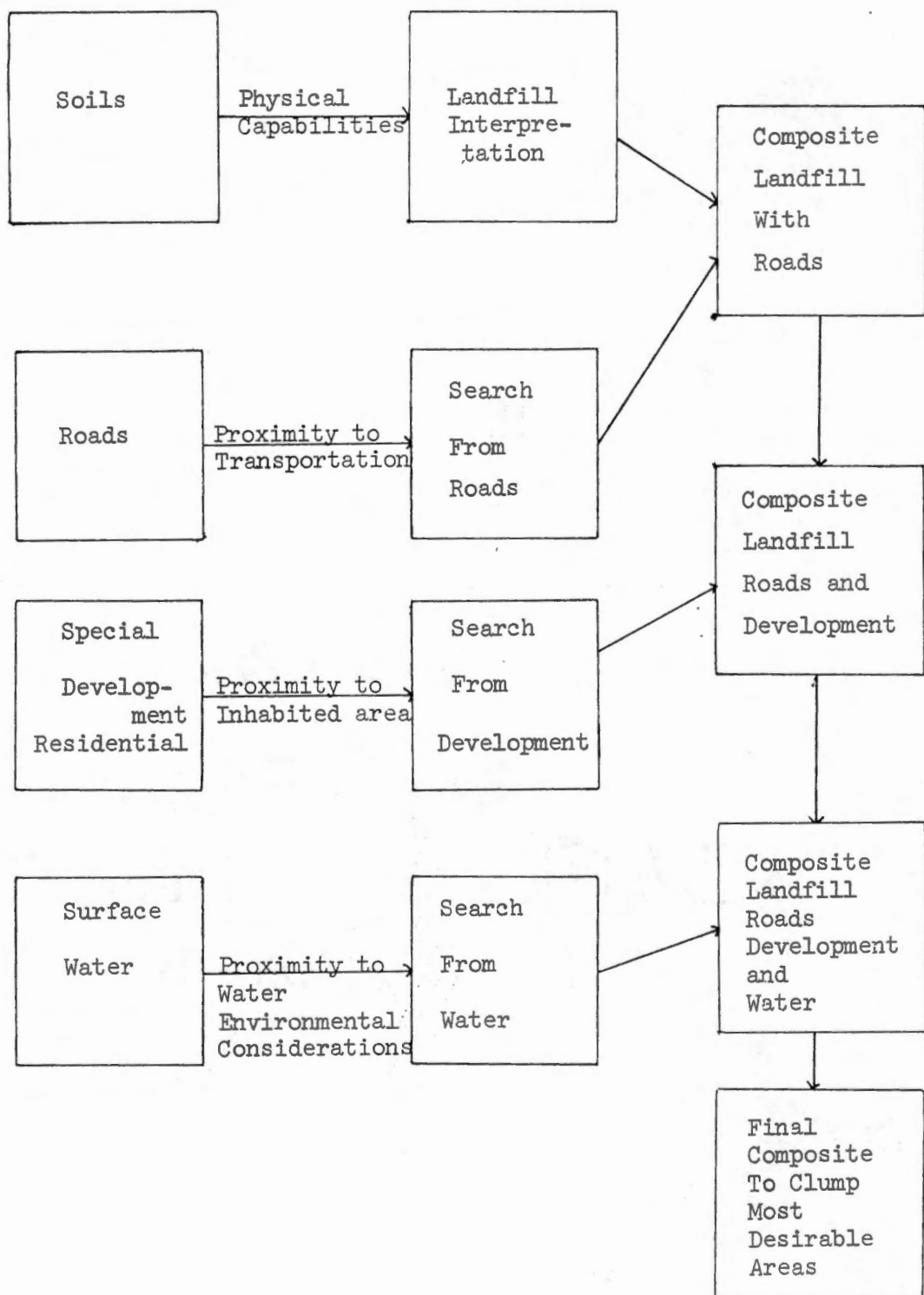


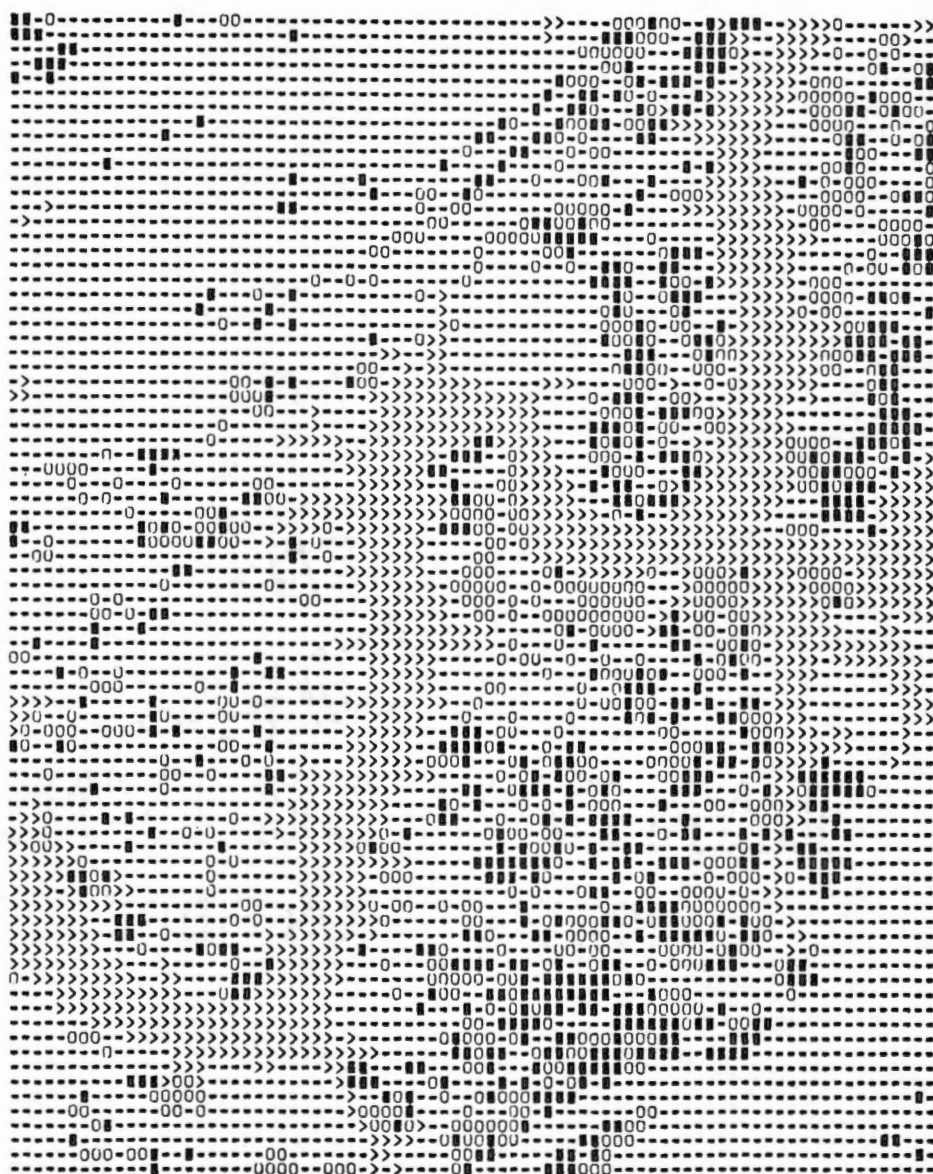
Figure 38. Flowchart showing the components of the landfill model.

Table 24. Proximity to medium and light duty roads in the Concord study area. Analysis and summary using the IMGRID system with road data from the topographic map.

Cells from Roads	Cells	Hectares	Acres	%
Roads in cell	713	778	1911	11.2
One cell away	1201	1303	3219	18.7
Two cells away	1007	1092	2698	15.7
Three cells away	838	909	2246	13.2
Four cells away	717	778	1922	11.2
Five cells away	585	634	1568	9.1
Six or more cells away	1339	1452	3588	20.9

potential landfill sites within the specified proximity to roads. The matrix between these two elements is shown in Figure 14 (page 79). The results of that matrix are displayed in Figure 40 and the area distribution is recorded in Table 25. About 59% of the area was rejected because of soil limitations or distance from transportation routes and 18% was water. The sites with slight limitations for sanitary landfill are the ones that we want to observe throughout this model. As interpreted from soils data (Table 16, page 117) these sites amounted to 13.8% of the study area. They were reduced to only 10.3% (Table 25) when transportation was added to the criteria. Also, other information is needed to locate a potential site.

c. Search from development. A factor that must be considered when locating a sanitary landfill is the concern of people about placement of a sanitary landfill in their community. People in subdivisions and other types of residences are interested in sites being as far away from them as possible. A search was performed to give some consideration to this human concern. Because of the size of the study area, it was decided to use a three cell search from development. The results of this search are displayed in Figure 41 and the area distribution is recorded in Table 26. More than 65% of the study area is greater than three cells away from development. Combination of this search with the composite from the landfill interpretation and search from roads shows potential landfill sites that meet specified criteria.



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 RESOURCE DOCUMENT: SOIL SURVEY U.S.D.A., SOIL CONSERVATION SERVICE,
 LOUDON, KNOX, AND BLOUNT COUNTIES, TENNESSEE

CONCORD QUADRANGLE, TENNESSEE
 SOUTHEASTERN PORTION 5 MINUTES PER SIDE

LEGEND

0 = SITES NOT SUITABLE UR > 5 CELLS FROM ROAD
 1 = SITES WITHIN 5 CELLS OF ROAD WITH SLIGHT LIMITATIONS
 2 = SITES WITHIN 5 CELLS OF ROAD WITH MODERATE LIMITATION
 3 = WATER

LEVELS

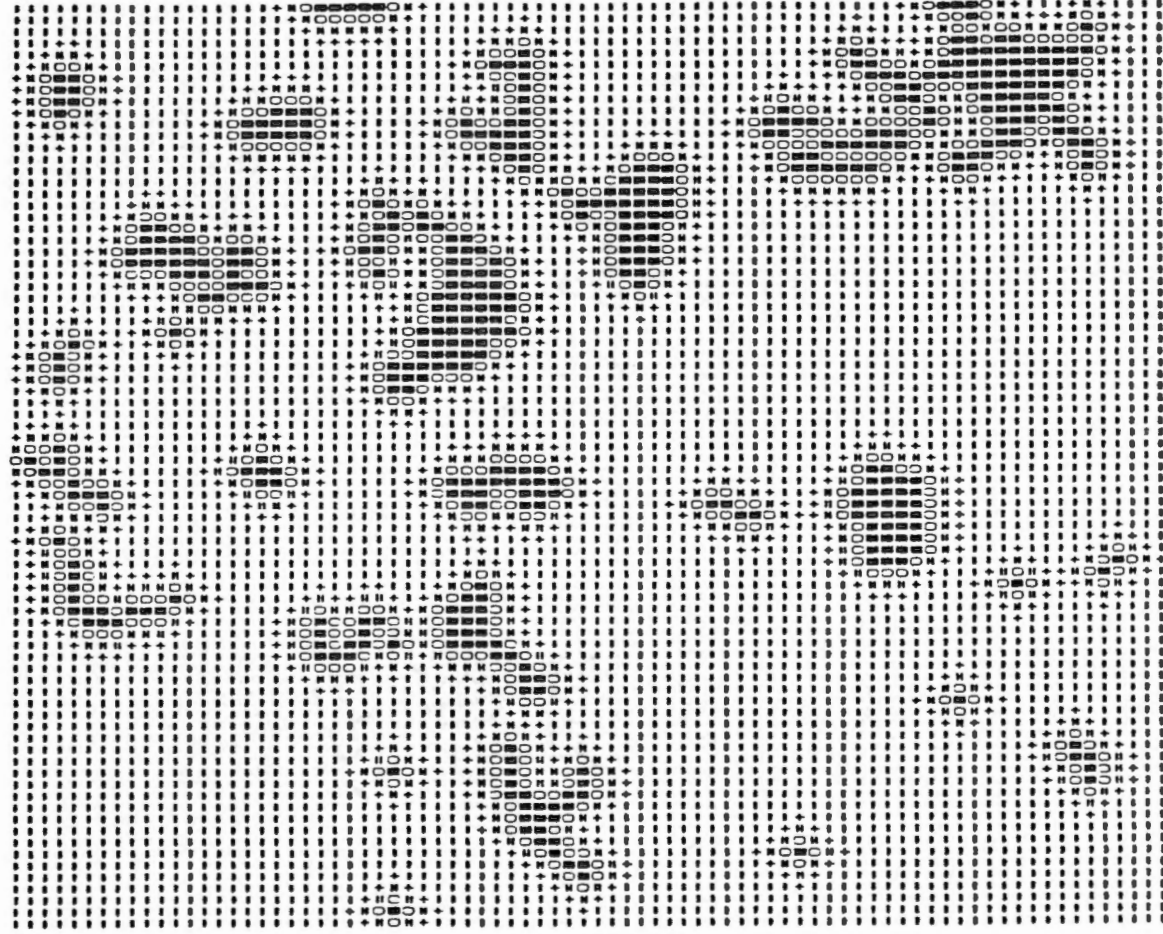
0	1	2	3
00000	00000	00000	00000
00000	00000	00000	00000
00000	00000	00000	00000
00000	00000	00000	00000
00000	00000	00000	00000

FREQUENCY 3792 662 801 1145

Figure 40. IMGRID composite of sanitary landfill interpretation and search from roads to show potential sites within five cells of roads for the Concord study area.

Table 25. Limitations for potential landfill sites in the Concord study area that are within five cells of roads. Analysis and summary using the IMGRID system with detailed soil map road location data.

Classes	Cells	Hectares	Acres	%
Not suited or too far from roads	3792	4112	10162	59.2
Slight	662	718	1774	10.3
Moderate	801	868	2146	12.6
Water	1145	1242	3069	17.9



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CONCORD QUADRANGLE, TENNESSEE
SOUTHEASTERN PORTION 5 MINUTES PER SIDE

LEGEND
+ = ORIGIN
0 = 1 CELLS FROM ORIGIN
1 = 2 CELLS FROM ORIGIN
2 = 3 CELLS FROM ORIGIN
3 = 4 CELLS FROM ORIGIN

(more than three cells from origin)

LEVELS
0 1 2 3 4
=====

FREQUENCY 473 539 589 627 4172

Figure 41. IMGRID proximity line printer map showing distance in cells from residential development for the Concord study area, based on 1979 quasi-land use.

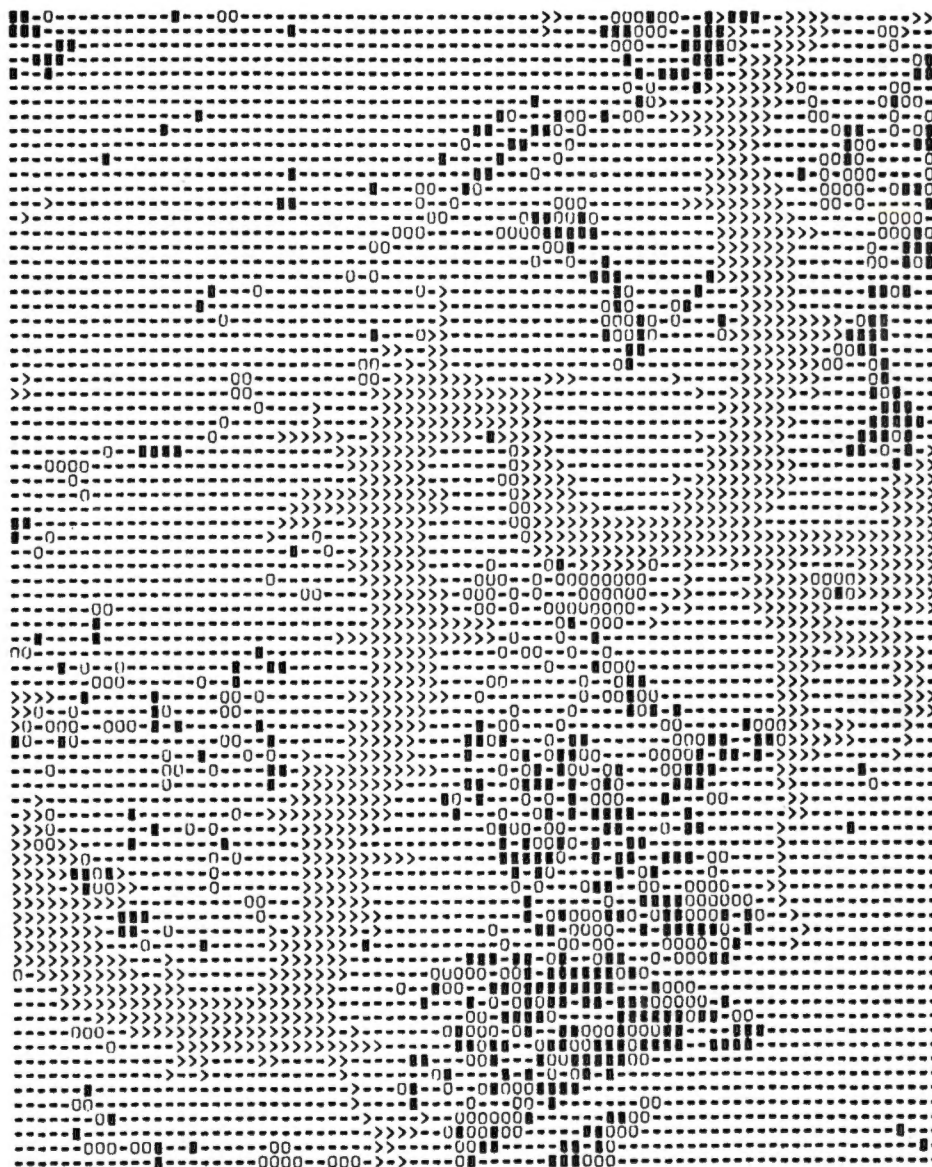
Table 26. Proximity to residential development in the Concord study area. Spatial search and summary using the IMGRID system with 1979 quasi-land use.

Classes	Cells	Hectares	Acres	%
Development in cell	473	513	1268	7.4
One cell away	539	584	1444	8.4
Two cells away	589	638	1578	9.2
Three cells away	627	680	1680	9.8
Four or more cells away	4172	4524	11181	65.2

d. Landfill sites near roads and away from development. The landfill composite showing nearness to roads (Figure 40) was combined with distance from development (Figure 41) to show potential landfill sites within the specified proximity to roads and distance from development. The matrix between these two elements is in Figure 15 (page 80). The results of application of that matrix are displayed in Figure 42 and the area distribution is in Table 27. The area with slight limitations for sanitary landfill decreased from 10.3% to 6.7% when developmental considerations were added. The effect of a landfill on the environment should be considered during planning.

e. Search from water. There are a host of problems that could be labeled environmental, but for this study we considered the pollution aspects, specifically water pollution. A search was performed to relate a sanitary landfill to environmental concerns. In the same manner as the search from development, a three cell search was made from lakes and streams. Distance in cells is displayed in Figure 43 and area distribution is in Table 28. Only 26.6% of the area was greater than three cells from water.

f. Landfill sites near roads and away from development and water. The landfill interpretation showing distance to roads and away from development (Figure 42) was combined with the distance from water (Figure 43) to show potential landfill sites that were within 5 cells of roads and more than 3 cells away from development and water. The matrix between these two elements is shown in



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SOUTHEASTERN PORTION 5 MINUTES PER SIDE

LEGEND

0 NOT SUITED OR WITHIN 3 CELLS OF DEVELOPMENT
1 SLIGHT LIMITATIONS < 3 CELLS OF ROADS AND > 3 CELL DEVELOPMENT
2 MODERATE LIMITATIONS < 5 CELLS OF ROADS AND > 3 CELL DEVELOPMENT
3 WATER

LEVELS

LEVELS	0	1	2	3
0	XXXXXX	XXXXXX	XXXXXX	XXXXXX
1	XXXXXX	XXXXXX	XXXXXX	XXXXXX
2	XXXXXX	XXXXXX	XXXXXX	XXXXXX
3	XXXXXX	XXXXXX	XXXXXX	XXXXXX
4	XXXXXX	XXXXXX	XXXXXX	XXXXXX
5	XXXXXX	XXXXXX	XXXXXX	XXXXXX
6	XXXXXX	XXXXXX	XXXXXX	XXXXXX
7	XXXXXX	XXXXXX	XXXXXX	XXXXXX
8	XXXXXX	XXXXXX	XXXXXX	XXXXXX
9	XXXXXX	XXXXXX	XXXXXX	XXXXXX
10	XXXXXX	XXXXXX	XXXXXX	XXXXXX
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13	XXXXXX	XXXXXX	XXXXXX	XXXXXX
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28	XXXXXX	XXXXXX	XXXXXX	XXXXXX
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65	XXXXXX	XXXXXX	XXXXXX	XXXXXX
66	XXXXXX	XXXXXX	XXXXXX	XXXXXX
67	XXXXXX	XXXXXX	XXXXXX	XXXXXX
68	XXXXXX	XXXXXX	XXXXXX	XXXXXX
69	XXXXXX	XXXXXX	XXXXXX	XXXXXX
70	XXXXXX	XXXXXX	XXXXXX	XXXXXX
71	XXXXXX	XXXXXX	XXXXXX	XXXXXX
72	XXXXXX	XXXXXX	XXXXXX	XXXXXX
73	XXXXXX	XXXXXX	XXXXXX	XXXXXX
74	XXXXXX	XXXXXX	XXXXXX	XXXXXX
75	XXXXXX	XXXXXX	XXXXXX	XXXXXX
76	XXXXXX	XXXXXX	XXXXXX	XXXXXX
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87	XXXXXX	XXXXXX	XXXXXX	XXXXXX
88	XXXXXX	XXXXXX	XXXXXX	XXXXXX
89	XXXXXX	XXXXXX	XXXXXX	XXXXXX
90	XXXXXX	XXXXXX	XXXXXX	XXXXXX
91	XXXXXX	XXXXXX	XXXXXX	XXXXXX
92	XXXXXX	XXXXXX	XXXXXX	XXXXXX
93	XXXXXX	XXXXXX	XXXXXX	XXXXXX
94	XXXXXX	XXXXXX	XXXXXX	XXXXXX
95	XXXXXX	XXXXXX	XXXXXX	XXXXXX
96	XXXXXX	XXXXXX	XXXXXX	XXXXXX
97	XXXXXX	XXXXXX	XXXXXX	XXXXXX
98	XXXXXX	XXXXXX	XXXXXX	XXXXXX
99	XXXXXX	XXXXXX	XXXXXX	XXXXXX
100	XXXXXX	XXXXXX	XXXXXX	XXXXXX

FREQUENCY 4313 425 517 1145

Figure 42. IMGRID composite showing limitations for potential land-fill sites within five cells of roads and more than three cells away from development for the Concord study area, based on 1979 quasi-land use.

Table 27. Limitations for potential landfill sites in the Concord study area that are within five cells of roads and greater than three cells from development. Spatial search and summary using the IMGRID system with detailed soil map data, 1979 quasi-land use data and road location data.

Classes	Cells	Hectares	Acres	%
Not suited	4313	4678	11559	67.3
Slight	425	461	1139	6.7
Moderate	517	560	1385	8.1
Water	1145	1242	3069	17.9

CONCORD QUADRANGLE, TENNESSEE
SOUTHEASTERN PORTION 5 MINUTES PER SIDE

LEVELS	0	1	2	3	4
FREQUENCY	1470	1236	1053	906	1705

Figure 43. IMGRID proximity line printer map of the Concord study area showing a three cell search from water, based on 1979 quasi-land use.

Table 28. Proximity to water in the Concord study area. Spatial search and summary using the IMGRID system with water location data from the topographic maps.

Classes	Cells	Hectares	Acres	%
Water	1470	1594	3939	23.0
One cell away	1236	1340	3312	19.3
Two cells away	1083	1174	2902	16.9
Three cells away	906	983	2428	14.2
Four or more cells away	1705	1849	4569	26.6

Figure 16 (page 81). The results of application of that matrix are in Figure 44 and the area distribution is in Table 29. By excluding those areas within 3 cells of water, the potential landfill sites with slight limitations decreased from 6.7% to 2.7%. Still, by observing Figure 44, one can see that sites with slight limitations for sanitary landfill are scattered throughout the study area. These sites meet all the criteria, but from a practical standpoint a single cell should not be considered as a possible landfill site. Therefore, some type of clumping is needed to cluster the larger sites and eliminate sites that are too small.

g. Landfill sites clustered. Through discussions with Mr. Michael Matthews of TVA's Solid Waste Management Program it was learned that no set amount of land is required for the development of a landfill. He said that small rural towns may require only 8 hectares (20 acres) over a period of 15 years. Larger cities would require 61 hectares (150 acres) or more. A city the size of Knoxville would use about 4 hectares (10 acres) per year. Some parts of a site may not be approved for a landfill by the state health department. Because suitable cells were scattered throughout the study area a one cell ASearch was performed to aggregate these sites. ASearch is illustrated in Figure 17 (page 82). In the ASearch each cell in the grid is given the sum total of each cell around it plus, if desired, the value of the cell that is being ASearch. In this study the value of the ASearch cell was included. The values obtained were recoded, giving the highest values to the best condition as shown

Table 29. Limitations for potential landfill sites in the Concord study area that are within five cells of roads and greater than three cells from development and water. Spatial search and summary using the IMGRID system with data from soil maps, road location, 1979 quasi-land use, and water location.

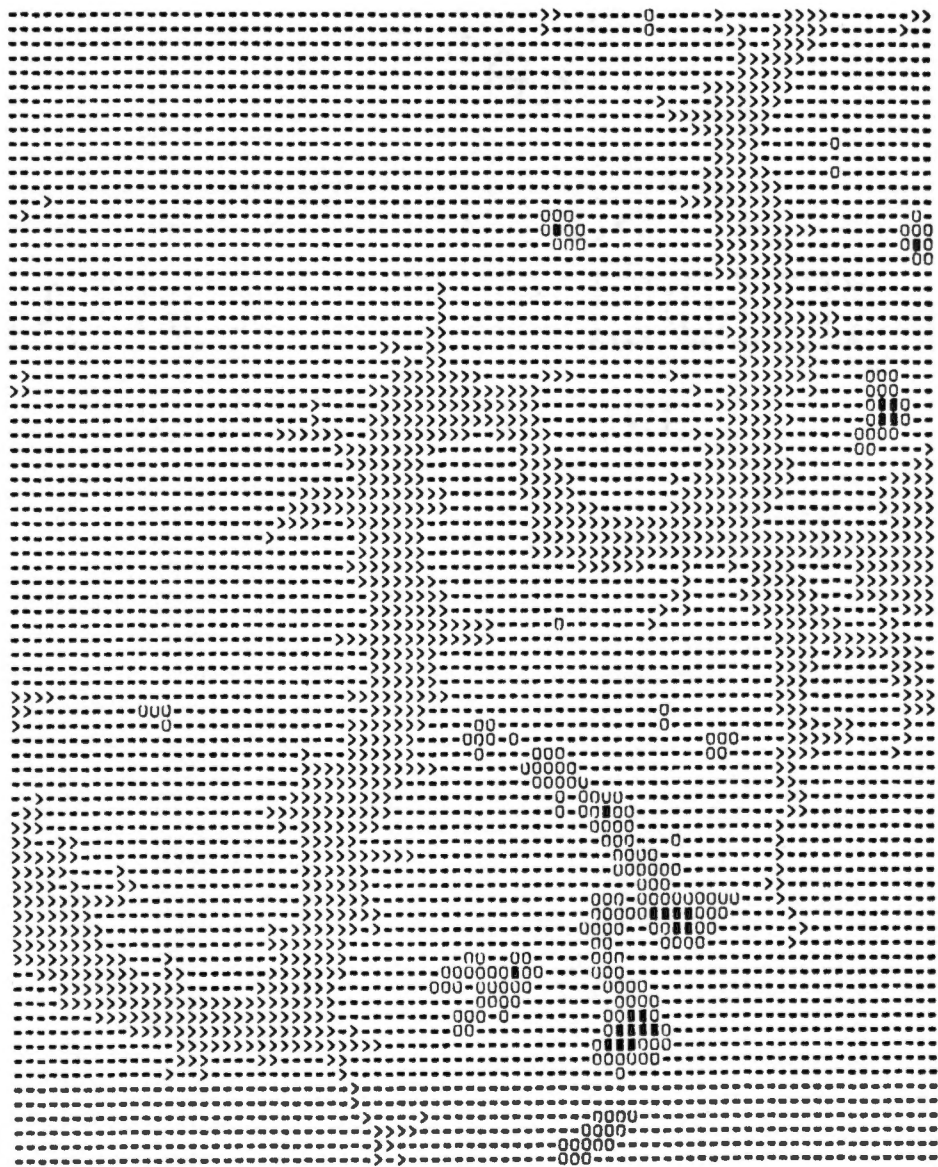
Classes	Cells	Hectares	Acres	%
Not suited	4877	5289	13070	76.2
Slight	170	184	456	2.7
Moderate	208	225	557	3.2
Water	1145	1242	3069	17.9

in Figure 18 (page 83). In this model the highest possible value was eighteen because only the best and second best conditions were considered. The classes were arbitrarily broken at 8 and 12. Values from 13 to 18 had slight limitations. Values below 7 were not suited. These values were then recoded by assigning slight limitations a value of 1, moderate limitations a value of 2, and values below 7 a value of zero. A map was then produced (Figure 45). The area distribution of the classes is recorded in Table 30. The aggregate of sites with slight limitations decreased from 2.7% before clumping to only 0.4% after clumping. Figure 45 shows that most of the sites that meet all the criteria for potential landfills are located in the southeastern part of the study area.

A map like Figure 45 is far more useful to planners than several maps showing each of the components of this map on separate sheets. This map shows the planner the location of potential landfill sites that are within 5 cells of roads and greater than 3 cells away from water and development. One map like this is superior to several maps in a meeting where decisions are made. It could save a planning commission a lot of time and money and may prevent a wrong decision. Sites considered to be too small were eliminated by clumping, utilizing the ASearch capability of IMGRID. Only sites with potential are left for consideration.

C. Comparison of the MIADS and IMGRID Systems

A comparison of the mapping and analysis techniques of IMGRID and MIADS showed that both systems are similar in most common



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 SOUTHEASTERN PORTION 5 MINUTES PER SIDE

LEGEND

0 = NOT SUITED
 1 = BEST SITES CLUMPED
 2 = MODERATE SITES CLUMPED
 3 = WATER

LEVELS	0	1	2	3
	5022	23	210	1145

Figure 45. IMGRID composite of the Concord study area showing clumped potential landfill sites within five cells of roads and more than three cells away from development and water, based on 1979 quasi-land use.

Table 30. Limitations of clumped potential landfill sites in the Concord study area that are within five cells of roads and greater than three cells from development and water. Spatial search and summary using the IMGRID system, based on 1979 quasi-land use.

Classes	Cells	Hectares	Acres	%
Not suited	5022	5447	13459	78.4
Slight	23	25	62	0.4
Moderate	210	228	563	3.3
Water	1145	1242	3069	17.9

characteristics. However, the IMGRID mapping system does have two characteristics that are not available in MIADS. One important characteristic of IMGRID is the ability to overprint characters, thus making gray level mapping possible. The overprinted IMGRID maps are much easier to read because patterns are easier to see.

Another capability offered by IMGRID that is not available in MIADS is the ability to do proximity to lines and points. This technique was used to create the sanitary landfill model. Searches were performed from roads, development, and water and combined with the sanitary landfill interpretation to demonstrate a powerful analysis technique that could be useful in the decision-making process. Analysis capability of MIADS is limited to simple procedures of overlaying one map on another.

Another thing to consider is relationship of the map scale to some other reference system. Because of the latitude of the study area, each of 1.08 hectare (2.68 acre) cells of the IMGRID system approximates a geodetic cell and the map can be enlarged or reduced easily to any scale. The MIADS system requires the use of two characters to identify each cell thus causing the maps to be wider than they are long. This problem can be compensated for in part by allowing more space between the rows. Adjustments in the shape of the MIADS maps must be made before cultural features such as roads can be added to the map.

Another thing that must be considered when comparing systems is the quality of the final product. The first thing that comes to

mind when comparing the IMGRID and MIADS maps is what can be seen by simply looking at the maps. When 3 to 5 classes are used, patterns are easily seen on IMGRID maps while all characters seem to run together on the MIADS line printer maps. When more than 5 classes are used on IMGRID line printer maps patterns become more difficult to see, but they are still more easily seen than 3 to 5 classes on MIADS maps. By assigning the proper set of symbols to IMGRID maps, the user can highlight a particular situation, thereby making good or bad conditions easy to see on the line printer map.

1. Advantages of MIADS and IMGRID

a. MIADS. The MIADS computer programs have several advantages:

1. The size of the area is not limited.
2. MIADS has the capacity to reproduce the original map as coded up to 2,200 characters.
3. Data encoded at the same scale can be combined to allow certain analyses to be made.
4. MIADS accepts data referenced as UTM, Geodetic, or State plane.
5. Data can be updated interactively on the time sharing terminal.
6. Tables are produced to show how many times each code occurs and MIADS calculates area and gives the percentages.
7. Data can be translated and combined with other data to produce a new map.

8. Boundary maps allow any area that is outlined as a separate boundary to be pulled out and analyzed.

b. IMGRID. The IMGRID programs allow a great deal of flexibility in handling resource data:

1. Data can be encoded as integers or alphanumeric characters.
2. The information can be displayed using gray level shading.
3. The system produces a frequency count to tell the user how many times each class appears on the map.
4. The data can be recoded to be useful in the analysis process.
5. Data can be combined with other data to produce a new map.
6. Searches can be performed to show proximity to places of interest such as roads, development, and water.
7. Data can be accepted from a variety of reference systems (UTM, Geodetic, and State plane).
8. The system can be used to cluster cells to obtain enough concentration in an area for a particular use.

2. Disadvantages of MIADS and IMGRID

a. MIADS. MIADS has several aspects that are undesirable:

1. The maps are hard to read because there is no overprinting. Patterns are hard to see.
2. Since it takes two characters to identify each cell, scaling is difficult.

3. Because of the scaling problem with the output, road overlays are hard to produce.
4. Data translations have to be made for the whole legend. The system does not allow recodes to be made in the analysis process.
5. The system has no means of showing proximity, thus lacking an important step in the analysis process.
6. The source map has to be cut into small strips because only 36 two character cells can be processed per strip.
7. The maps are hand coded a line at a time.
8. Data are entered into the system on keypunched cards.

b. IMGRID. Some shortcomings of the IMGRID system are:

1. In most computer centers IMGRID is strictly batch with no interactive capabilities even for editing.
2. The maps are hand coded a line at a time.
3. The system can map only twenty levels at a time from any file.
4. The map is limited to 32,500 cells on the IBM 360. Since this limit is due to the computer, the limit is much greater with the IBM 370.
5. Data cannot be combined with data of different scale.
6. Data are entered into the system on keypunched cards.

3. Operational Comparisons

Here are some examples of how these advantages and disadvantages affected this study. MIADS capability to map 2,200

characters proved beneficial when land use and suitability for farmland were combined. This combination produced 50 different classes that were mapped according to the matrix in Figure 10 (page 75). The ability of MIADS to map a large number of unique characteristics is an advantage because a map produced by a matrix between suitability for farmland and land use, for example, can be grouped manually to show many different interpretations involving these two interpretations. This manual grouping reduces the number of classes to be interpreted and produces a map that is easier to understand. The matrix between suitability for farmland and land use was also produced by the IMGRID system. However, IMGRID can map only 20 classes per computer run. The matrix values (Figure 11, page 76) had to be recoded to achieve the number of classes that could be handled. One apparent problem is the difficulty in choosing a symbol set that will show patterns on a large number of classes. MIADS does not have the capability to produce gray level maps. The maps of this study clearly show this to be a disadvantage. The number of levels MIADS could map would be cut drastically if gray level mapping were added to the system.

Another important advantage of IMGRID is the ability to do proximity to lines and points. This capability was very useful in developing the landfill model. Searches from roads, development, and water were combined with sanitary landfill interpretations to show potential landfill sites. Also, land use was combined with sanitary landfill interpretations to show sites that did not conflict

with development. MIADS was at a big disadvantage because it could not do proximity to lines or points. Only simple overlays could be performed.

Advantages and disadvantages of MIADS and IMGRID are due mainly to their analytical capabilities. One big advantage in analytical capabilities of IMGRID over MIADS was demonstrated with the landfill model.

IMGRID and MIADS were compared on the basis of their capabilities, common characteristics, advantages, and disadvantages. MIADS proved to be a good system for making simple interpretations, but its value as a mapping or analytical tool is questionable. On the other hand, IMGRID has analytical capabilities that far exceed those of MIADS. For example, the modeling capability and the ability to do proximity searches make it possible for IMGRID to be used more extensively in the decision-making process. This is demonstrated by use of IMGRID in the landfill model. Also, it can be combined with other programs such as route optimization for roads or transmission lines to show the most economical way to get from point A to point B, or to calculate the route that would have the least impact on the environment. Although not demonstrated in this study, this capability is suggested here to show that IMGRID is a powerful tool that can be used easily in the decision-making process.

Other factors make IMGRID more desirable than MIADS. One is IMGRID's capability to highlight points of interest to the user by overprinting characters. Also, a histogram and legend are provided

with each map to show how each class is represented. MIADS provides tables and statistics for each map on a separate page, but MIADS maps are harder to use than IMGRID maps. However, by using an external process MIADS maps can be produced in color. Such maps are easier to interpret. In this study comparisons indicated that IMGRID line printer maps are much easier to understand than MIADS maps.

4. Costs

More information is needed before comparing costs of the two systems. IMGRID can be obtained by paying a small royalty fee to Harvard University. MIADS can be obtained from the SCS. Since cost for the MIADS system was not determined, comparison of the cost for operating the two systems can only be estimated.

5. Summary of Comparisons

Since costs were not determined, the two systems were compared only on their capabilities for analysis and mapping. Based on these capabilities there can be no doubt that IMGRID is a far better system than MIADS. Both systems can be used by people with little or no computer training. Since both systems are easy to use and there is no evidence to support costs, a user would probably choose IMGRID over MIADS mainly because of the quality of the maps and the analytical capabilities of IMGRID.

D. Quality Control in Spatial Analysis

The purpose of this section is to describe the process of quality control in spatial analysis and to give examples of quality control problems encountered.

1. Spatial Analysis Techniques

To show how spatial analysis techniques are employed in this research project Figure 38 (page 139) will be used as an example of one type of an analysis technique. The techniques demonstrated in the flow chart (Figure 38) show how data can be manipulated in a computer assisted spatial analysis system. The first technique is an interpretation of the source data. In this example there were four source documents: (1) a soil map, (2) a map of roads, (3) a map showing residential development, and (4) a map showing surface water. The soil map was interpreted by evaluating the physical capabilities of each mapping unit for sanitary landfill development. A map showing roads, development, and water was interpreted by assigning values to each of the attributes that would allow them to be used in the analysis process.

The analysis process is outlined in the following steps. First, the source documents were interpreted for various uses. Secondly, the Search keyword of IMGRID was used to show proximity to roads, development, and water. The Overlay keyword of IMGRID was then used to make composite maps from the interpretive maps and searches. Landfill interpretations from soils were combined with a search from

roads to give a map that showed potential landfill sites that were close to roads. This map was then combined with a search from development and the resulting composite showed sites that were close to roads and away from development. This composite was then combined with a search from water to produce a composite showing sites that were close to roads and away from development and water. To eliminate sites that were too small to be considered for use as a sanitary landfill some clustering was done utilizing the ASearch keyword of IMGRID. To summarize the techniques used in this outline, four techniques were employed: (1) interpretation, (2) search (proximity), (3) overlay, and (4) clumping.

The last step in the exercise on spatial analysis techniques was to take one or more of the composite maps, starting with Figure 44 (page 153) and examine specific cells in different parts of the map tracing back through all data and assumptions (procedures and interpretive data) to determine how the results turned out the way they did. A similar analysis was also performed on Figure 45 (page 156) to explain why clustering of some cells on Figure 44 resulted in errors on Figure 45.

2. Quality Control Techniques

This selection was included to identify ways in which errors could be controlled or minimized in a spatial analysis system. A lot of errors that occur in such a system are due to errors in record keeping or the lack of record keeping. For example, the criteria for the land use map identified grassland but when maps were printed it was called

pastureland. Additional confusion was caused by using terms which did not clearly distinguish prime farmland from other important farmland. These kinds of errors can be eliminated or minimized if records are maintained to insure that consistency occurs throughout the analysis process. Some examples of kinds of analyses and types of records that should be kept in order to maintain good quality will be discussed under Methods for Controlling Errors.

3. Source of Data Errors

There are many places where errors can occur in the data. Some examples are: source document errors, encoding and data entry errors, and interpretation errors.

a. Source document errors. These are errors that are due to imperfections in the original map. For example, a soil map may have a soil body delineated with two different map symbols. Another example would be delineation with no map symbol. These kinds of errors are detected easily when soil maps are digitized manually because each delineation on the map is examined more closely than for practically any other use.

A second kind of source document error may be a land use map that does not reflect current conditions. If the area is field checked the situation seen on the ground would differ from that indicated on the map. One way of minimizing errors of this type would be to conduct thorough ground truth analysis before encoding the map.

A third cause of source document errors can occur if an attribute such as water is taken from two source documents. For example, water was encoded from both a soil map and a topographic map. Conflicts resulted when attributes from both of those maps were used together. Conflicts resulting from use of two source documents can be minimized by selecting one document as the best source and converting the same cells in files of another source documents to correspond.

b. Encoding and data entry errors. Errors may occur also when data are entered on the coding form or keypunched. The data should be checked many times to make sure that encoding errors have been detected and eliminated. After keypunching the cards should be checked against the coding form to be sure that the information on the card is the same as that on the coding form. It also helps to have the data checked by someone that is not involved in the project.

c. Interpretation errors. Errors can occur because of incorrect interpretation of the source data. These can be minimized by establishing criteria that will cover all anticipated situations and maintaining records of the interpretations made throughout the project. Criteria must be rigorously maintained, or where interpretations differ from established criteria, such departure should be indicated.

4. Methods for Controlling Errors

There are ways of controlling or reducing errors in a spatial analysis system. The first step is to establish rules for dealing with errors in the source documents such as two symbols in a soil body or no data to fill gaps between county boundaries. Stay within

the rules established or keep records that show where different information was used and give reasons why the changes were made. Other ways of controlling errors are: (1) check coding form carefully to be sure data are encoded correctly, (2) check keypunched card against the coding form to make sure they match, (3) produce interpretive maps, look for obvious errors, then place a clear overlay of the topographic map over them to be sure that the map is correct according to topography, (4) make a series of maps for each class represented on the computer map that will allow you to examine any cell that may look out of place by placing the clear overlay on the separations to see if soils that are supposed to occur on the hills are showing up in the valleys, (5) choose several points on the final maps and trace them backward through all operations performed on the maps to determine if the system operated properly, and (6) keep good records so that consistency as well as quality can be maintained throughout the analysis process.

5. Explanation of Errors in Analysis Maps

This section gives specific examples of errors in the analysis maps and points out how errors in the source documents can cause errors in the analysis maps.

a. Situation. Figures 34 and 35 (pages 128 and 129) are composite maps produced by combining the soil interpretations for farmland with the land use interpretations from the topographic map. Both of these documents had water encoded as an attribute and it did

not always occupy the same reference point on the map. Some areas where there were conflicts are circled on Figure 34 (page 128).

b. Explanation. Because there were conflicts between the two source documents it was decided to override the water symbol on the soil map with the symbol on the land use map. This was done because the land use map was more current than the soil map. However, the required update was inadvertently not made in two cells near the top of Figure 24 (page 102) and Figure 28 (page 113). This error was explained in the discussion of these figures.

c. Situation. It was apparent that there were errors in Figure 45 (page 156) that could not be explained from simple observations. Detailed studies of the situations were required. This was accomplished by selecting a potential problem area for each of the three counties on Figure 44 (page 153) and tracing one cell in each county back to the original soil and land use data. Starting at the upper left corner of the map the cells were numbered 1 through 6400. Cell 56 in Knox County at the top of the map showed a slight limitation for landfill development.

d. Explanation. Cell 56 was traced backward starting with Figure 44, a composite of suitable landfill sites that are close to roads and away from development and water. The next step was a search from water. This cell met the required criteria. Going backward through the analysis indicated that the cell met all criteria for searches from development and roads. Then an examination of the source

documents showed that this cell was encloded as Bolton silt loam, eroded, rolling phase, from the soil survey. Land use was woodland. This phase of the Bolton series was rated as having slight limitation for landfill development in this research. Therefore, the evaluation provided no explanation for cell 56 on Figure 45 (p. 156) being rated as having moderate limitations instead of not suited for landfill development.

e. Situation. Two other cells in this study were traced back to the original data. Cell 3853 in Loudon County and cell 3329 in Blount County, respectively. Figure 44 (page 153) showed these two cells to have slight limitations for landfill development.

f. Explanation. These cells, 3853 and 3329, were traced backward through the analysis as was cell 56. Cell 3853 was found to have a slight rating throughout the evaluation. The source document showed this cell to be Minvale silt loam, gently sloping phase, and the land use was grassland. Cell 3329 showed a slight limitation for landfill development on the computer map and the source document showed a slight limitation for the Minvale silt loam, eroded sloping phase. However, this evaluation did not explain errors at these cell locations on the computer map Figure 45 (p. 156). Therefore, the errors had to be caused by the clustering of cells on Figure 44 that produced Figure 45. An evaluation was then made to determine what happened and why it happened. The 3 cells previously used were also used in this evaluation. It was found that according to the established criteria these cells should have been rated not suited for landfill

development on Figure 45 (page 156) instead they were rated moderate. A check of the computer input card showed that the break between moderate and not suited was 8 not 9 as shown on an earlier version of Figure 18 (page 83). However, this did not explain why a value of 7 was assigned to the moderate class in Knox and Loudon counties and a value of 6 was assigned to the moderate class in Blount County. From this evaluation it was determined that there is a problem with the ASearch keyword of IMGRID. Although minor errors occurred in Figure 45 as a result of using this keyword it appears to be a valuable tool. However, the problem should be corrected for future use.

g. Situation. One situation that did not cause errors in the maps produced did leave an inconsistency in record keeping. Figures 10 and 11 (pages 75 and 76) are matrixes set up to show how farmland is being used. Figure 10 uses the MIADS system and Figure 11 used IMGRID. The classes for land use were not listed in the same order on both figures.

h. Explanation. This switch in symbol order does not affect computer performance or the output, but more careful record keeping would assure consistency.

6. Summary of Quality Control Techniques

Several aspects of data manipulation need close attention to control quality in computer assisted spatial analyses. One is the checking for errors in the source documents. Conflicts among source

documents must be resolved before analysis is performed. Data must be encoded and entered into the system correctly to avoid errors. Errors in interpretation of source data also create problems. Close attention to all of these problems will result in more accurate results.

CHAPTER VII

SUMMARY AND CONCLUSIONS

There is a need for computerization of soil survey information. Several computer programs are available to aid in the processing of interpretive maps. However, selection of a program depends upon the availability of equipment and personnel and the way the interpretive maps are to be used.

Some information on fifty-five systems was assembled from literature. Several of these systems are capable of producing interpretive maps, performing analyses, and managing a data base with soils information. An evaluation of these systems showed that some of them were capable of performing the functions stated as objectives for this study.

From the list of 55 systems many were not selected for use in the study because: (1) they could not be obtained in the time allotted for the study; (2) the researcher could not have direct access to digitizing equipment; (3) some of the systems had been compared by other researchers; (4) some polygon systems were impressive in company literature, but were not selected for this study because conversations with users showed they do not perform as promised; and (5) polygon and line segment systems are expensive to operate because of large computer storage requirements. Other systems were dismissed because of distance from the researcher.

The two systems selected for further study were the IMGRID and MIADS spatial analysis systems because: (1) these systems were made

available for the study; (2) the agencies using the systems had a genuine interest in having them compared; (3) both systems have been used successfully for producing interpretive maps from soil information. IMGRID has several million acres of soil data encoded as 1.08 hectare (2.68 acre) cells and MIADS has several million acres encoded as 6 hectares (15 acres) or larger cells; and (4) a comparison of these two systems is beneficial because the SCS and TVA have a cooperative agreement for exchanging information. MIADS is used by the SCS and IMGRID is used by TVA. Information exchanges would be easier if both agencies used the same system.

From the comparison of IMGRID and MIADS the following conclusions may be drawn:

1. Both IMGRID and MIADS can be used successfully to produce single purpose and single factor maps. However, IMGRID maps are more usable as printed because their overprinted gray level maps show patterns better.
2. The analytical capabilities of IMGRID exceed those of MIADS which is limited to simple overlay procedures. IMGRID's ability to do proximity searches is one reason for its superiority in analysis capabilities.
3. Both IMGRID and MIADS have the capability to manage large volumes of data, but differ in what they can do with these data. Both systems can combine data from one file with that of another to create a new file, but IMGRID can perform analyses on data from each file before combination.

For example, after presence of water from the land use file was combined with water from the roads and streams map, a 3 cell distance from water search was performed before combination with sanitary landfill interpretations. This composite was then combined with a search from roads and development to show potential landfill sites that were close to roads and away from development and water.

4. Both systems were capable of joining soils information from three surveys, all on different scales. However, because the same code did not always represent the same soil in all three counties, interpretations were joined instead of original data.
5. The two systems used grid cells as the method of input. Data were encoded a line at a time and keypunched onto cards for entering the computer. The data were manipulated and retrieved interactively by MIADS. All functions of IMGRID were performed by using cards.
6. Edits and updates are easy with both systems, but because IMGRID overprints, errors are easier to find. When errors are found they can be updated either one cell at a time or as a group of cells. Since MIADS does not overprint, errors on the map are difficult to find, but once they are located they can be updated easily.
7. The best information system available today may be a combination of IMGRID for its analytical capabilities and

a good polygon system for its management function.

However, for analytical capabilities alone the best single system is IMGRID.

In conclusion: (1) problems caused by the nature of soils data can be solved by recoding the data when necessary or by joining interpretive maps to avoid errors caused by differences in county legends; (2) MIADS is a good tool for simple analyses and data storage, but has little value as an analytical tool; (3) IMGRID is better than MIADS for resource planning; (4) information in the literature indicates that polygon systems represent the original data with more precise resolution than IMGRID and MIADS, but have not been around long enough or are too expensive to have been proven effective in handling and analysis of large amounts of resource data; (5) our comparison of the analyses and maps produced in this study left little doubt that IMGRID is better than MIADS to aid the decision-maker in resource planning; and (6) from literature evaluations and the comparison with MIADS it was learned that IMGRID has analytical capabilities that far exceed those of MIADS and many of the polygon systems. For this reason it was concluded that IMGRID was the best system by far for producing interpretive maps from soils and other resource information.

Further research is needed in at least three areas:

1. The IMGRID and MIADS systems should be compared where the researcher has complete control over both. Then they could be treated the same and tested for all functions the

systems are capable of performing. An accurate comparison of cost is needed.

2. Some new polygon systems should be tested for effectiveness in handling resource data to determine their interactive capabilities and assess their adaptability for small offices.
3. The best grid system and the best polygon system should be compared to evaluate their usefulness in the planning processes. The resolution needed and the graphic product desired should be considered when selecting a computer-assisted system.

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APPENDIXES

APPENDIX A

Criteria for Rating Soil Mapping Units

Important Farmland

1. Soil mapping units classified as prime farmland were taken from SCS inventory and monitoring memorandum Tn-1 November 1978. This is an interoffice memo that can be obtained from the SCS state office in Nashville, Tennessee.
2. Soil mapping units classified as other important farmland were also based on criteria outlined in SCS memorandum Tn-1.
3. Soil mapping units classified as other land were the remainder of the units except for wetland.
4. Wetness limitation—Soils that are wet or in depressed areas.
5. Water.

Depth to Bedrock Values Assigned (1-4)

1. 0-0.6 m (0-2 ft.)
2. 0.6-1.2 m (2-4 ft.)
3. 1.2-1.8 m (4-6 ft.)
4. 1.8 m+ (6+ ft.)

Slope Values Assigned (1-5)

1. 0-2%
2. 2-5%
3. 5-12%
4. 12-25%
5. 25%+

Limitations for Sanitary Landfill

The criteria for landfill interpretations were selected by modifying criteria established by the Metropolitan Planning Commission and TVA for locating feasible landfill areas in Knox County.

1. Slight	2. Moderate	3. Severe
>6' to water table	>6' to water table	<6' to water table
>6' to bedrock	>6' to bedrock	<6' to bedrock
<2"/hr. perc.	<2"/hr. perc.	>2"/hr. perc.
0-12% slopes	12-20% slopes	>20% slopes
No flooding	No flooding	Occasional flooding
Class 1 stoniness	Class 2 stoniness	

Capability Classes

Capability classes for the soils in Blount and Loudon counties were taken directly from the soil surveys. In Knox County, capability classes were determined by matching phases of soil series with capability classifications in surrounding counties and in the official series descriptions.

Erosion Potential

1. Slight	2. Moderate	3. Severe
Class I, II, IIIw, and IVw land	Class IIIe and IIIs land	Class IVe, IVs, VI, and VII land
Nearly level	<12% slope	>12% slope
Slow runoff or runoff	Moderate runoff	Rapid runoff

APPENDIX B

Table 31. Ratings of Loudon County soils for interpretations and factors.

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
ACB	1	1	4	2	1	1	2
ACC	2	2	4	3	1	2	3
BA	3	1	2	1	3	1	2
BNC	4	3	1	3	3	2	3
BND	5	3	1	4	3	3	4
BOC2	6	2	4	3	1	3	3
BOD2	7	3	4	4	2	3	4
BOE2	8	3	4	6	3	3	5
CAC	9	3	4	3	1	2	3
CAD	10	3	4	4	2	3	4
CAE	11	3	4	6	2*	3	4
CAF	12	3	4	7	3	3	5
CBC	13	3	1	3	3	2	3
CMB2	14	1	4	2	1	2*	2
CMC2	15	2	4	3	1	2	3
CMC3	16	2	4	4	1	3	3
CMD2	17	3	4	4	2	3	4
CMD3	18	3	4	4	2	3	4
CME2	19	3	4	6	3	3	5
COA	20	1	3	1	3	1	1
COC	21	2	3	1	3	2	3
CRE3	22	3	3	6	3	3	5
CUC2	23	2	4	3	2	2	3
CUD2	24	3	4	4	3	3	4

Table 31 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
DCB2	25	1	4	2	1	2*	2
DCC2	26	2	4	3	1	3	3
DCC3	27	2	4	4	1	3	3
DCD2	28	3	4	4	1	3	4
DCD3	29	3	3	4	3	3	4
DEB2	30	1	4	2	1	2*	2
DEC2	31	2	4	3	1	3	3
DED2	32	3	4	4	2	3	4
DEE2	33	3	4	6	3	3	5
DWC3	34	2	4	4	1	3	3
DWD3	35	3	4	4	2	3	4
DWE3	36	3	4	6	3	3	5
EM	37	1	4	1	3	1	1
ER	38	1	4	1	3	1	1
ETB	39	1	4	2	1	1	2
ETC2	40	2	4	3	1	2	3
ETD2	41	3	4	4	2	3	4
FAB2	42	1	2	2	3	2*	2
FAC2	43	2	2	3	3	3	3
FAD2	44	3	2	4	3	3	4
FBC3	45	3	2	4	3	3	3
FBD3	46	3	2	4	3	3	4
FBE3	47	3	2	6	3	3	5
FCC	48	2	4	3	1	2	3
FCD	49	3	4	4	2	3	4
FCE	50	3	4	6	3	3	5
FCF	51	3	4	7	3	3	5
FDD3	52	3	4	6	2	3	4

Table 31 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
FDE3	53	3	4	6	3	3	5
FDF3	54	3	4	7	3	3	5
FSB	55	1	3	2	3	2*	2
FSC	56	2	3	3	3	2	3
FSD	57	3	3	4	3	3	4
FSE	58	3	3	4**	3	3	5
FSF	59	3	3	7	3	3	5
FTC3	60	2	3	4	3	3	3
FTD3	61	3	3	4	3	3	4
FTE3	62	3	3	6	3	3	5
GC	63	1	3	1	3	1	1
GE	64	1	3	1	3	1	1
GL	65	3	2	7	3	3	5
GS	66	3	1	7	3	3	5
HA	67	1	4	2	3	1	1
HB	68	1	4	2	3	1	1
HCC	69	2	4	3	2	2	3
HEB	70	1	4	4**	2	2**	2
HEC2	71	2	4	3	2	3	3
HNA	72	1	4	1	3	1	1
HNC	73	1	4	1	3	2	3
LCB	74	2	4	2	3	2*	3
LDB	75	1	4	2	3*	1	2
LDC2	76	2	4	2	3	2*	3
LEB	77	1	3	2	3	2*	2
LHD	78	3	1	4	3	3	4
LHE	79	3	1	7	3	3	5
LHF	80	3	1	7	3	3	5

Table 31 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
LN	81	1	4	2	3	1	1
LO	82	1	4	2	3	1	1
LSC	83	3	1	4	3	3	3
LSD	84	3	1	4	3	3	4
LSE	85	3	1	7	3	3	5
LTC	86	3	1	3	3	3	3
LTD	87	3	1	4	3	3	4
LTE	88	3	1	7	3	3	5
LU	89	2	4	2	3	1	1
MA	90	3	1	7	3	3	1
ME	91	4	4	3	3	1	1
MRC2	92	2	4	3	2	3	3
MSB	93	1	4	2	1	2**	2
MSC2	94	2	4	3	1	3	3
NE	95	1	3	1	3	1	1
NOC	96	2	4	3	2	3	3
NOD2	97	3	4	4	3	3	4
QA	98	3	1	7	3	3	5
RB	99	4	4	4	3	1	1
RO	100	3	1	7	3	3	5
SAB	101	1	4	2	3	2**	2
SCB	102	1	4	2	3	2**	2
SCC	103	2	4	3	3	3	3
SEC	104	2	2	3	3	3	3
SKB2	105	2	2	2	3	2*	2
SKC2	106	2	2	3	3	3	3
SKD2	107	3	2	4	3	3	4
SLC3	108	3	1	4	3	3	3

Table 31 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
SLD3	109	3	1	4	3	3	4
STD	110	3	1	4	3	3	4
STF	111	3	1	7	3	3	5
SVF	112	3	1	7	3	3	5
TA	113	1	4	4	3	1	1
TBC2	114	2	2	3	3	3	3
TCC3	115	3	2	4	3	3	3
TCD3	116	3	2	4	3	3	4
TD	117	3	1	7	3	3	4
TGC3	118	3	2	4	3	3	3
TGD3	119	3	2	4	3	3	4
TGE3	120	3	2	6	3	3	5
TFG3	121	3	2	7	3	3	5
TLC2	122	2	2	3	3	3	3
TLD2	123	3	2	4	3	3	4
TLE3	124	3	2	6	3	3	5
TLF	125	3	2	7	3	3	5
WGC2	126	2	3	3	3	3	3
WGD2	127	3	3	3**	3	3	4
WGE3	128	3	3	6	3	3	5
WKD3	129	3	3	6	3	3	4
WKE3	130	2	3	6	3	3	5
WLB2	131	1	3	2	3	2*	2
WLC	132	2	3	3	3	3	3
WLC2	133	2	3	3	3	3	3
WLD2	134	3	3	4	3	3	4
WLE2	135	3	3	6	3	3	5
WMD3	136	3	3	4	3	3	4

Table 31 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
W0	137	1	4	2	3	1	1
Y (no data)	138	0	0	0	0	0	0
Z (water)	139	5	5	8	4	4	6

*Where additional information was available the ratings were assigned values incorporating this additional information and therefore the ratings differ from those indicated by the criteria in Appendix A.

**Mistakes made in interpretation of original data.

Table 32. Ratings of Knox County soils for interpretations and factors.

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
AA	1	2	2	2	3	2*	3
AB	2	1	3	2	1*	1	2
AC	3	3	1	4	3	3	5
AD	4	3	2	4	3	3	4
AE	5	3	1	7	3	3	5
BA	6	3	2	3	3	3	3
BB	7	3	1	7	3	3	5
BC	8	3	1	4	3	3	4
BD	9	3	1	3	3	3	3
BE	10	3	1	7	3	3	5
BF	11	3	4	3	2	3	4
BG	12	2	4	2	1	2*	3
BH	13	3	4	4	3	3	5
BK	14	3	4	4	2	3	4
BL	15	2	4	3	2	3	3
BM	16	3	4	4	3	3	5
CA	17	1	2	2	3	2*	2
CB	18	1	4	2	3	1	1
CC	19	3	4	4	2	3	4
CD	20	3	4	3	2	2	3
CE	21	3	4	7	3	3	5
CF	22	3	4	4	2	3	4
CG	23	3	4	3	2	2	3
CH	24	3	4	7	3	3	5

Table 32 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
CK	25	3	1	4	3	3	4
CL	26	3	1	4	3	3	3
CM	27	3	2	3	3	3	3
CN	28	3	2	3	3	2	2
CO	29	1	4	2	3	1	1
CP	30	1	4	1	3	1	1
CR	31	1	4	1	3	1	1
CS	32	1	4	1	3	1	1
CT	33	2	3	2	1*	3	3
CU	34	3	3	3	2*	3	4
CV	35	2	3	2**	1*	1	3
CW	36	1	3	2	1*	1	2
CX	37	3	3	4	2*	3	4
CY	38	2	3	3	1*	2	3
DA	39	3	2	4	3	3	4
DB	40	3	2	7	3	3	5
DC	41	3	2	4	3	3	4
DD	42	3	2	6	3	3	5
DE	43	3	1	6	3	3	4
DF	44	3	1	4	3	3	5
DG	45	3	1	4	3	3	5
DH	46	2	4	2	1	2*	3
DK	47	1	4	2	1	1	2
DL	48	3	3	3**	1*	3	4
DM	49	2	2	3	3	2	3
DN	50	1	4	2	1	1	2
DO	51	3	3	4	2*	3	4
DP	52	2	3	3	1*	3	3

Table 32 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
DR	53	2	4	2	1	2	3
DS	54	1	4	2	1	1	2
DT	55	3	4	3**	2	2	4
DU	56	2	5**	2	1	2*	3
DV	57	3	3	4	3	3	5
DW	58	1	4	1	1	1	2
DX	59	3	4	4	2	3	4
DY	60	2	4	3	1	2	3
EA	61	1	4	1	3	1	2
EB	62	2	4	1	3	1	3
EC	63	1	4	1	3	1	2
ED	64	1	4	2	1	1	2
EE	65	3	4	3**	2	3	4
EF	66	2	4	2	1	2	3
EG	67	3	4	2	1	1	2
EH	68	1**	4	3	1*	3	4
FA	69	3	2	4	3	3	4
FB	70	2	2	2	3	3	3
FC	71	2	2	2	3	2*	2
FD	72	3	4	4	2	3	4
FE	73	2	4	3	1	2	3
FF	74	3	4	6	3	3	5
FG	75	3	4	4	2	3	4
FH	76	2	4	3	1	2	3
FI	77	3	4	6	3	3	5
FJ	78	3	4	4	2	3	4
FK	79	3	4	4	1	3	3
FL	80	3	4	7	3	3	5

Table 32 (continued)

	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
FM	81	3	4	4	2	3	4
FN	82	2	4	2	1	2	3
FO	83	2	4	2	1	1	2
FP	84	3	4	3**	2	3	4
FQ	85	2	4	2	1	2*	3
FR	86	2	4	2	1	1	2
FS	87	3	4	4	2	3	4
FT	88	2	4	2	1	2	3
FU	89	2	4	2	1	1	2
FV	90	3	4	3	2	3	4
FW	91	2	4	2	1	2*	3
FX	92	2	4	2	1	1	2
FY	93	3	4	4	2	3	4
FZ	94	2	4	3	1	3	3
GA	95	2	4	3	3	1	3
GB	96	1	4	2	3	1	3**
GC	97	2	4	3	3	1	2**
GD	98	1	4	2	3	1	2
GE	99	3	2	7	3	3	5
GF	100	3	2	7	3	3	5
GG	101	3	2	7	3	3	3
GH	102	3	2	7	3	3	3
GK	103	3	1	7	3	3	4
GL	104	4	4	4	3	1	1
HA	105	1	4	2	3	1	1
HB	106	1	4	2	3	1	1
HC	107	1	4	1	3	1	1
HD	108	1	4	1	3	1	1

Table 32 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
JA	109	3	2	4	3	3	3
JB	110	2	2	3	3	3	3
JC	111	2	2	3	3	2	2
JD	112	2	2	3	3	3	3
LA	113	2	2	2	3	1	3
LB	114	1	3	3	3	1	3
LC	115	2	3	3	3	1	3
LD	116	1	3	2	3	1	3
LE	117	3	1	7	3	3	4
LF	118	3	1	7	3	3	5
LG	119	1	4	2	3	1	1
MA	120	3	1	7	3	1	3
MB	121	4	4	4	3	1	1
MC	122	3	1	7	3	3	4
MD	123	3	1	4	3	3	3
ME	124	3	1	7	3	3	5
MF	125	3	1	3	3	2	2
MG	126	3	1	7	3	3	5
MH	127	3	1	7	3	3	3**
MK	128	3	1	7	3	3	5
ML	129	3	1	6	3	3	4
MM	130	3	1	7	3	3	5
MN	131	3	1	7	3	3	5
NA	132	2	4	2	2	1	3
NB	133	1	3	2	3	1	2
NC	134	2	4	3	3	2	3
OA	135	1	4	2	3	1	1
PA	136	4	4	4	3	1	1

Table 32 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
RA	137	1**	3	2	3	1	1
SA	138	1	4	2	3	1	3
SB	139	3	1	4	3	3	4
SC	140	3	1	3	3	3	3
SD	141	2	1	2	3	2*	2
SE	142	3	1	4	3	3	4
SF	143	3	1	4	3	3	3
SG	144	3	1	2	3	3	3
SH	145	2	1	2	3	2	2
SK	146	3	1	3	3	3	3
SL	147	2	1	2	3	2	2
SM	148	3	1	4	3	3	3
SN	149	3	1	3	3	3	2
SO	150	1	4	2	3	1	1
SP	151	1	4	1	3	1	1
SR	152	1	4	1	3	1	1
SS	153	3	1	4	3	3	5
ST	154	3	1	4	3	3	3
SU	155	3	1	7	3	3	5
TA	156	2	2	3	3	3	3
TB	157	3	2	2	3	3	2
TC	158	3	1	4	3	3	4
TD	159	3	2	4	3	3	3
TE	160	3	2	4	3	3	4
TF	161	3	4	3	3	3	3
TG	162	3	1	7	3	3	5
TH	163	3	4	4	3	2	4
TK	164	2	3	2	3	2*	3

Table 32 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
TL	165	3	1	7	3	3	5
TM	166	3	3	4	3	2	4
TN	167	2	3	2	3	1	3
TO	168	3	2	7	3	3	5
TP	169	1	4	4	3	2	1
WA	170	3	3	4	2*	3	4
WB	171	3	3	4	2*	3	4
WC	172	2	3	3	2*	2	3
WD	173	1	4	2	2	1	2
WE	174	2	4	3	3	3	3
WF	175	1	4	2	3	2*	2
Y (no data)	176	0	0	0	0	0	0
Z (water)	177	5	5	8	4	4	6

*Where additional information was available the ratings were assigned values incorporating this additional information and therefore the ratings differ from those indicated by the criteria in Appendix A.

**Mistakes made in interpretation of original data.

Table 33. Ratings of Blount County soils for interpretations and factors.

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
AA	1	1	4	2	1	1	2
AB	2	2	4	3	1	2	3
AC	3	3	4	4	2	3	4
AE	4	3	2	4	3	3	4
AH	5	3	4	6	3	3	4
AL	6	3	2	6	3	3	4
AN	7	2	4	3	2	2	3
AO	8	3	4	4	2	3	4
AP	9	2	2	3	3	2	3
AR	10	3	2	4	3	3	4
AT	11	3	2	4	3	3	4
BA	12	1	4	1	3	1	2
BB	13	1	4	1	3	1	2
BC	14	2	3	1	3	2	3
BD	15	2	1	3	3	2	3
BE	16	3	1	6	3	3	5
BF	17	3	1	6	3	3	5
BG	18	3	2	4	3	2*	1
CA	19	3	2	4	3	2**	3
CB	20	3	1	4	3	3	4
CC	21	2	2	2	3	2*	2
CD	22	3	2	3	3	2	3
CE	23	3	2	4	3	3	4
CF	24	3	2	4	3	3	4
CG	25	3	1	3	3	2	3
CH	26	2	4	4	1	2*	3
CK	27	3	3	4	1*	3	4

Table 33 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
CL	28	1	4	2	1	2*	2
CM	29	2	4	3	1	2	3
CN	30	3	3	4	2*	3	4
DA	31	3	1	6	3	3	5
DB	32	3	1	4	3	3	4
DC	33	3	1	6	3	3	5
DD	34	3	1	3	3	3	3
DE	35	3	1	4	3	3	4
DF	36	3	1	6	3	3	5
DG	37	2	3	4	2*	3	3
DH	38	3	3	4	2*	3	4
DK	39	1	4	2	1	2	2
DL	40	2	4	3	1	2	3
DM	41	3	3	4	2*	3	4
DN	42	2	4	3	2	2	2
DO	43	3	4	4	2	3	4
DP	44	2	4	4	2	3	3
DR	45	3	3	4	2*	3	4
DS	46	1	4	2	1	2*	2
DT	47	2	4	3	1	2	3
DU	48	2	4	4	2	3	4
DV	49	2	3	3	3	2	3
DW	50	3	2	4	3	3	4
DX	51	3	1	6	3	3	5
DY	52	3	2	4	3	3	3
DZ	53	3	2	4	3	3	3
DAA	54	1	3	2	3	2*	2

Table 33 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
DAB	55	2	3	3	3	2	2
DAC	56	3	2	4	3	3	3**
DAD	57	3	2	6	3	3	5
EA	58	1	4	1	3	1	1
EB	59	1	4	1	3	1	2
EC	60	1	3	1	3	1	2
ED	61	1	4	2	1	2*	2
EE	62	2	4	3	1	2	3
FA	63	2	2	4	3	3	3
FB	64	1	3	2	3	2*	2
FC	65	2	3	3	3	2	3
FD	66	3	4	4	2	3	4
FE	67	3	4	4	2	3	4
FF	68	3	4	6	2*	3	4
FG	69	3	4	6	3	3	5
GA	70	1	3	1	3	1	2
GD	71	3	4	7	3	3	5
GC	72	3	3	7	3	3	5
HA	73	1	3	2	3	1	1
HB	74	1	3	2	3	1	1
HC	75	1	3	2	3	1	1
HD	76	1	3	2	2*	2*	2
HE	77	2	3	3	2*	2	3
HF	78	2	3	6	2*	2	2
HG	79	2	3	6	2*	2	3
HH	80	1	3	2	3	2*	2
HK	81	1	3	2	3	2*	2
HL	82	1	3	3	3	3	3

Table 33 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
HN	83	2	3	3	3	3	3
JC	84	2	2	6	3	2*	3
JD	85	3	2	6	3	3	4
JE	86	1	3	2	3	2*	2
JF	87	2	3	3	3	3	3
JG	88	3	2	4	3	3	4
JH	89	3	2	6	3	3	5
LA	90	1	3	2	3	1	2
LB	91	1	3	2	3	2*	2
LC	92	2	2	3	3	2	3
LD	93	3	2	7	3	3	5
LE	94	1	4	2	3	1	1
LF	95	3	1	3	3	2	3
LG	96	3	1	4	3	3	4
LH	97	2	1	3	3	2	2
LK	98	3	1	3	3	2	3
LL	99	3	1	4	3	3	4
MA	100	4	4	3	3	1	1
MB	101	1	4	2	1	2*	2
MC	102	2	4	3	1	3	3
MD	103	3	2	4	3	3	4
ME	104	3	1	6	3	3	5
MH	105	1	3	2	3	2*	2
MK	106	2	3	3	3	3	3
MG	107	3	2	4	3	3	4
ML	108	3	2	4	3	3	4
NA	109	1	2	1	3	1	2
PA	110	1	3	2	3	2*	2

Table 33 (continued)

Symbol	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
PB	111	2	3	3	3	3	3
PC	112	4	4	3	3	1	1
RA	113	3	4	7	3	3	5
RB	114	3	3	7	3	3	5
RC	115	3	1	7	3	3	5
RD	116	3	1	7	3	3	3
RE	117	3	1	7	3	3	5
RF	118	3	1	7	3	3	5
SB	119	1	4	1	3	1	1
SC	120	1	4	1	3	1	1
SD	121	1	4	1	3	1	1
SE	122	2	1	4	3	3	3
SF	123	2	2	2	3	2*	2
SG	124	2	1	3	3	2	3
SH	125	1	3	1	3	1	1
SK	126	1	3	1	3	1	1
SL	127	1	3	1	3	1	1
SM	128	3	3	7	3	3	4
TA	129	3	2	4	3	3	4
TB	130	2	2	4	3	3	3
TC	131	3	2	4	3	3	4
TD	132	2	3	3	3	3	3
TE	133	3	2	4	3	3	4
TF	134	3	2	7	3	3	3
TG	135	3	2	7	3	3	4
TH	136	3	1	6	3	3	5
TL	137	3	2	4	3	3	4
TM	138	3	2	6	3	3	5

Table 33 (continued)

	Code	Prime Farmland	Depth to Bedrock	Capability Class	Sanitary Landfill	Erosion Potential	Slope
TN	139	2	3	3	3	3	3
TO	140	3	2	4	3	3	4
TP	141	3	2	6	3	3	5
TR	142	3	2	6	3	3	5
TS	143	3	2	6	3	3	5
WA	144	1	3	2	3	2*	2
WB	145	2	3	3	3	3	3
WC	146	3	2	4	3	3	4
WD	147	1	3	2	3	1	2
WE	148	1	4	2	3	1	1
Y (no data)	149	0	0	0	0	0	0
Z (water)	150	5	5	8	4	4	6

*Where additional information was available the ratings were assigned values incorporating this additional information and therefore the ratings differ from those indicated by the criteria in Appendix A.

**Mistakes made in interpretation of original data.

Table 34. Example from Loudon County soils legend as recoded for the MIADS system.

Symbol	Recode		Recode
ACB	AA	DED2	DH
ACC	AB	DEE2	DI
BA	BA	DWC3	DJ
BNC	BB	DWD3	DK
BND	BC	DWE3	DL
BOC2	BD	EM	EA
BOD2	BE	ER	EB
BOE2	BF	ETB	EC
CAC	CA	ETC2	ED
CAD	CB	ETD2	EE
CAE	CC	FAB2	FA
CAF	CD	FAC2	FB
CBC	CE	FAD2	FC
CMB2	CF	FBC3	FD
CMC2	CG	FBD3	FE
CMC3	CH	FBE3	FF
CMD2	CI	FCC	FG
CMD3	CJ	FCD	FH
CME2	CK	FCE	FI
COA	CL	FCF	FJ
COC	CM	FDD3	FK
CRE3	CN	FDE3	FL
CUC2	CO	FDF3	FM
CUD2	CP	FSB	FN
DCB2	DA	FSC	FO
DCC2	DB	FSD	FP
DCC3	DC	FSE	FQ
DCD2	DD	FSF	FR
DCD3	DE	FTC3	FS
DEB2	DF	FTD3	FT
DEC2	DG	FTE3	FU

APPENDIX C

QUESTIONNAIRE ABOUT COMPUTERIZATION
OF SOILS INFORMATION

by

MILTON ALLEN

1. Have any of the published soil surveys in your State been put in computer retrievable form?
Yes _____ No _____
2. If answer is yes to question one, what procedures are you using?
3. In your opinion is there a need for rapid display of soils interpretation?
Yes _____ No _____
4. How much does it cost to produce an interpretive map on a county format or 7-1/2 minute quadrangle?
County _____ Quadrangle _____ Not estimated _____
5. What are your needs in the area of computerized soils information?
6. What type of computer hardware or software, or both, do you believe will be necessary to get the job done?
7. What referencing system are you using (UTM, Geodetic, etc.)?
UTM _____ Geodetic _____ Other _____
8. Are you familiar with the advance mapping (AMS) that is developed by the Soil Conservation Service?
9. Are you using Polygons _____? Cells _____?
Explain techniques and equipment needed.

10. We are currently using manual coding techniques. Please share your ideas on automatic coding procedures if you use them.
11. If you are working with automatic coding procedures, what would your estimate costs be? Compare this with manual coding techniques.
12. Can you produce color computer maps? Yes___ No___
13. If so, what are the procedures used to produce such a map? How much does it cost to produce a color computer map for a county?
14. What method or procedure is used to fit the computer printout to a base map?
15. Do you have suggestions on how registration problems may be handled when trying to fit a computer generated map to a base map?
16. What procedures are being used to insure accuracy of data? Explain some ways that you think will be effective in validation of data.
17. Are any attempts being made to rid the soils maps of distortion, such as redrafting or are they being coded as is? Explain.
18. Do you exaggerate narrow streams and small lakes or ponds so they will show on the completed computer map? Yes___ No___
19. If answer to previous question is no, do you show streams and other water by manual or computer overlay or by other means?
20. List any other ideas you have about a study of this type.

APPENDIX D

Description of IMGRID Keyword Functions

1. ASearch—This process creates a new element by searching around points on the grid for a defined distance and summing those values in the element being searched.
2. End—This keyword causes the system to cease execution and stores the current system parameters in the element record file. The keyword also produces an end run list unless it is suppressed.
3. Interp—The keyword allows the user to read in alphanumeric data instead of integer data. A data legend is also read in and IMGRID uses it to transform the alphanumeric data into integer form which other IMGRID keywords can handle.
4. Map—This keyword creates a display of an existing or previously created element. Displays can only be made of elements which have values in the range of 0-19.
5. Matrix—Creates a new element which identifies the relative matrix position of each cell when two elements are compared. The column element is specified on the keyword card and the row element is read from a continuation card which automatically follows the keyword card. The maximum number of rows or columns is "9".
6. Overlay—Creates a new element by assigning new values to a set of old values. When continuation elements are specified the subsequent rescale values override the previous values when the rescale value is greater than the previous value.

7. Recode—Creates a new element by assigning new values to a set of old values.
8. Reloc—Moves a data element from one location to another in the data element file.
9. Reject—Creates a new element which identifies a set of cells which may be rejected from subsequent analysis if the reject element is specified.
10. Rename—Assigns a new name in the element file to the element specified.
11. Search—Creates a new element which measures the number of cells from specified "search condition" cells to every cell in the grid.
12. Symbol—Permits the specification of a special symbolism set. The system has stored six symbol sets available to the user.
13. Text—Permits the insertion of descriptive information into the output stream at any point.
14. Update—Allows direct assignment of value to a specific grid cell position on a cell-by-cell basis.
15. XChange—Creates a new file from an old file by allowing the user to group old values in any way, and to assign any value to the numbers in these areas.
16. XMatrix—Creates a new element in which the rescale values are identified by two elements which define the rows and columns of a matrix.

17. XRecode—Creates a new element by replacing values in an existing element with user-specified rescale values. XRecode can be used to rescale values outside the range 0-19 and values outside the range 0-9 can be assigned.
18. Zone—Creates a new file.
19. Endt—Is not a keyword but it is needed to tell the system where the text end so that the next keyword can be read.

VITA

Milton Allen was born in Somerville, Tennessee, on April 21, 1948. He attended elementary school in that city and was graduated from Fayette Ware High School in May 1966. The following September he entered Tennessee State University, and in June 1970 he received a Bachelor of Science degree in Agronomy. He began study toward a Master's degree at Tennessee State University in June 1970. This degree was awarded in June 1971.

After a 15-month tour of duty with the United States Army, he accepted a position with the Soil Conservation Service as a Soil Scientist. In September 1973 he entered The University of Tennessee, Knoxville. He returned to duty with the Soil Conservation Service in June 1974. He again entered The University of Tennessee, Knoxville, in September 1976. He received the Doctor of Philosophy degree with a major in Plant and Soil Science in March 1984.

Mr. Allen will be employed with the Department of Interior, Office of Surface Mining, after graduation.

He is married to the former Jerry Ann Craft of Elcampo, Texas. They have two children, a son Adrian Jamil, and a daughter Alicia JaNelle.