

## COMPUTER GRAPHICS: A PILOT STUDY

by

William E. Kelsh  
Graduate Research Assistant

and

Daniel D. McGeehan  
Principal Research Analyst

(The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agencies.)

Virginia Highway & Transportation Research Council  
(A Cooperative Organization Sponsored Jointly by the Virginia  
Department of Highways & Transportation and  
the University of Virginia)

Charlottesville, Virginia

September 1978  
VHTRC 79-R18

## ENVIRONMENTAL RESEARCH ADVISORY COMMITTEE

MR. E. T. ROBB, Chairman, Asst. Environmental Quality Engineer, VDH&T  
MR. M. C. ANDAY, Assistant Head, VH&TRC  
MR. R. E. BLASER, University Distinguished Professor, VPI & SU  
MR. L. E. BRETT, JR., District Engineer, VDH&T  
MR. W. L. BRITTLE, JR., Director of Engineering, VDH&T  
MR. A. R. CLINE, District Environmental Coordinator, VDH&T  
MR. R. V. FIELDING, Materials Engineer, VDH&T  
MR. R. L. HUNDLEY, Environmental Quality Engineer, VDH&T  
MR. A. B. JOHNSON, Assistant Construction Engineer, VDH&T  
MR. R. C. LOCKWOOD, Transportation Planning Engineer, VDH&T  
MR. D. D. MCGEEHAN, Research Analyst, VH&TRC  
DR. TOM STEPHENS, Associate Professor of Civil Engineering, VPI & SU  
MR. W. P. TUCKER, Right-of-Way Engineer, VDH&T  
MR. R. G. WARNER, Assistant Construction Engineer, VDH&T  
MR. ROBERT WELTON, Environmental Coordinator, FHWA  
MR. J. E. YEATTS, Assistant Location & Design Engineer, VDH&T

## SUMMARY

In meeting its responsibilities, the Environmental Quality Division collects and compiles extensive data. Because of the detail and volume of these data, decision makers, planners, and the public find them difficult to assimilate.

Computer mapping, a data display technique which can process large amounts of environmental data and produce output in mapped form, appeared to be a method by which these vast amounts of data could be simplified and thus be used more efficiently than is presently possible.

This report presents the results of a pilot study using computer graphics techniques with data from the Winchester area. The program SYMAP was evaluated, data on several variables were collected, and some potential problems related to developing computer mapping for environmental evaluation were identified.



## COMPUTER GRAPHICS: A PILOT STUDY

by

William E. Kelsh  
Graduate Research Assistant

and

Daniel D. McGeehan  
Principal Research Analyst

## INTRODUCTION

The passage of the National Environmental Policy Act of 1969 (NEPA) marked the institutionalization of "environmental awareness" in the transportation planning process. In response to the NEPA and other legislation to protect the environment the Virginia Department of Highways and Transportation established its Environmental Quality Division in 1970. The Division is charged with the responsibility for incorporating environmental considerations in the transportation planning process.

One of the Division's major responsibilities is to evaluate the impacts of proposed transportation facilities and, when necessary, to prepare environmental impact statements for such facilities. One of the major problems in the preparation of these documents arises in the initial data collection phase. Baseline environmental data must be assembled to assess the existing state of the environment in the general area of a proposed transportation facility. This information, which includes data on air and water quality, and existing and proposed land use, along with geological, topographical, and archaeological data, is found scattered among local, state, and federal agencies which, in turn, are similarly scattered throughout the state. Sometimes this information is incomplete or obsolete and must be updated or recompiled to meet the requirements of the Department. Too often certain data cannot be found elsewhere and must be collected by Department personnel. The time and money costs incurred by the Department in the initial data collection for environmental assessments can be considerable.

Another problem facing the Environmental Quality Division is the presentation of analyses of environmental data to administrators and decision makers not familiar with the technical aspects and limitations of such studies. Often environmental information is inefficiently used by people who must use it in making important decisions because of its sheer volume and detail. Additionally, the public, which has even less familiarity with such technical information, may be unable to use it to best advantage. In these days of

increased citizen awareness and participation in the transportation planning process it is extremely important that on environmental issues communications between the Department and local government and citizenry be very clear.

#### PROBLEM STATEMENT

There is a need for some means by which the Environmental Quality Division can collect, store in one place, and retrieve baseline environmental information rapidly and inexpensively for use in assessing environmental impacts. Additionally, it would be useful if the environmental data to be disseminated by the Division could be displayed in a summary, easily digestible fashion to promote the communications and understanding between technical and non-technical people.

#### PILOT STUDY

A pilot study was conducted to examine the feasibility of applying techniques from the expanding field of computer graphics to the needs of the Environmental Quality Division cited above. Generally defined, computer graphics techniques involve the use of combinations of computer hardware and software to produce machine processed data in a graphic rather than tabular format. Of particular interest to the Department might be the use of computer cartography to produce maps to summarize tabular environmental data for a given study area in an easy to read, understandable format.

#### COMPUTER CARTOGRAPHY

The science of computer cartography has resulted from the merger of techniques from computer science and geography. Computer made maps take advantage of the modern computer's ability to manipulate large volumes of data and produce graphic displays. Computer maps can be manipulated to fit the needs of the user. They can be produced at any scale and size. They can show a single variable or a combination of variables and can have legends and other explanatory notes printed within the map border. They can be stored on magnetic tape or disc, and can be produced and reproduced rapidly and inexpensively. Computer maps can be output on a line printer, a pen plotter, or a cathode-ray tube device.

Much of the current research in computer cartography is being conducted at Harvard University's Laboratory for Computer Graphics and Spatial Analysis in Cambridge. Harvard has developed a number of computer mapping software packages (canned programs) which are available for public purchase. These software packages (currently there are seven) have slightly different computer hardware and data input requirements. The prospective purchaser must decide which program or combination of programs best fits his needs. The purchase price for each program is generally under \$1,000. All of Harvard's programs have been designed for implementation on an IBM 370 computing system, which is of the same configuration as the Department's facility.

Figure 1\* is an example of a computer produced map of soil associations in the Winchester, Virginia, area. This map was produced by the computer program SYMAP using a standard line printer at the University of Virginia's CDC Cyber 172 computing facility. SYMAP was developed at Harvard during the 1960's and is currently the most widely distributed general purpose computer mapping software package. The program can produce maps containing point, line, or areal data, or combinations of these. By electing certain built-in program options, SYMAP users can manipulate the size and scale of output maps and the symbols used to distinguish map features. Program SYMAP can focus on specific portions of a map (i.e. a blow-up), can be programmed to include certain data features and exclude others, and can include cosmetic features such as legends and directional arrows within the map border. All SYMAP output is produced on a standard line printer on standard computer paper. All of the maps produced for this study were made by SYMAP.

#### STUDY DESIGN

The main objective of this study was to gain familiarity with the capabilities of computer mapping software. SYMAP was selected to make the maps for this study because of its availability in the University of Virginia's program library and because of its general purpose nature. To illustrate the capabilities of SYMAP, and computer mapping in general, several aspects of computer mapping techniques were examined. The first was the use of computer cartography for the storage and retrieval of environmental data. The second was

---

\*All figures are attached.

the use of computer program options to manipulate raw environmental data and to display it. The last was the use of computer overlay routines to compose a series of computer made maps, a technique which could be of use in environmental assessments.

#### STUDY AREA

The study area selected was the city of Winchester and its immediate environs. An important concern in the use of computer mapping techniques is the selection of a suitable base map of the study area. The base map serves as a frame of reference in the preparation of each computer map and ensures proper registration when the maps are overlaid. Because of their availability, widespread use, and convenient scale it was decided that one of the United States Geological Survey's (U.S.G.S.) 1/24,000 scale quadrangle sheets would be the best base map for this study. To simplify data collection, the study area was defined as all of the area lying within the cordon line shown in Figure 2, which also fell within the U.S.G.S. Winchester quadrangle. The size of this study area is approximately 24 mi.<sup>2</sup>.

#### DATA SELECTION

The first consideration after the selection of the study area was the choice of environmental variables to be used. Although many, perhaps a hundred or more, variables could be identified, only four basic items were chosen. It is felt that these variables are representative of the types of data items commonly used in environmental assessments. The four data variables selected were:

1. Existing land use
2. Historic sites
3. Characteristics of soils
4. Existing road system.

The data details for each of the four variables were first mapped on the U.S.G.S. Winchester quadrangle sheet chosen as the base map. Using a procedure known as digitizing\*, the data details for each variable were encoded into a format acceptable to SYMAP. Computer maps were produced for each variable at the same scale as the base map (1" = 2,000').

---

\*Process by which mapped data are converted into numerical data.



Figures 3 and 4, the soil and land use maps, are examples of SYMAP areal maps. Figure 5, the historic sites map, is an example of point data output, and Figure 6, the road system map, shows how SYMAP handles line data.

#### INFORMATION STORAGE AND RETRIEVAL

Computer cartography adds a new dimension to the use of computers in information storage and retrieval systems. Computer programs such as SYMAP have the capability of producing machine language images of computer maps which can be stored on magnetic tape or disc and be recalled rapidly and inexpensively. It is possible to store many of these machine language map images on a single tape, thus a large amount of environmental data can be stored in a small space. Computer mapping routines can be programmed to search through these stored map images, reprocess the data, and print out a map.

It is important to emphasize that the primary function of computer mapping programs is the display of information. Before programs such as SYMAP can be used as proposed, a great deal of work must be done to collect and organize environmental data in computer compatible format. The usefulness of computer maps is completely dependent on the quality and quantity of the environmental data used as input to the programs. In turn, the quality and quantity of the environmental information collected is dependent on the data needs of the Environmental Quality Division, the ways in which the information will be used, and the limits of the resources which the Department can commit toward the establishment of a computerized environmental data bank.

#### MAP MANIPULATION

Assuming that an environmental data bank will be developed and that computer mapping programs will be used to gain access to it, a number of other computer program features can be used to manipulate the base data. Program options allow the user to select any portion of a stored computer map and expand or reduce its scale by any amount. Figure 7 is an example of a blowup of a portion of the land use map (Figure 4). The expanded portion of Figure 4 was produced at a scale four times greater than the original. Care must be taken not to blow up a map to a scale which exceeds the resolution of the data it represents or else significant distortions occur.

By way of example some other features of computer mapping will be demonstrated.

One of the Environmental Quality Division's responsibilities is to make evaluations of proposed alternative transportation corridors. Part of the procedure involves the identification of environmentally sensitive areas within a project study area. Environmentally sensitive areas are generally poor locations for transportation facilities for either engineering, economic, political, or administrative reasons and would normally be identified as such in an environmental assessment. Through the use of appropriate map symbols areas of identified environmental sensitivity could be shown on computer maps. Further, degrees of environmental sensitivity could be distinguished by using shadings of varying intensities. Figure 8 is an example of how environmentally sensitive soil types might appear on a computer map of the study area. Three levels of environmental sensitivity\* have been defined: areas of little or no sensitivity, areas of moderate sensitivity, and areas of considerable sensitivity.

Figure 3 has been reproduced alongside Figure 8 to show how computer mapping programs such as SYMAP can be instructed to aggregate elementary data items into large groupings. The five soil associations in Figure 3 have been regrouped into three environmental sensitivity classes in Figure 8. Further, the user can select the map symbols used to identify these aggregated areas. The intensity of map shading assigned to each sensitivity class in Figure 8 has been chosen according to the severity of environmental limitations present in each area. Thus the darkest areas of the map represent areas of greatest environmental sensitivity and the lightest areas represent areas of least sensitivity. A map of this type is useful to the decision maker or planner untrained in soil science because it shows the location of potential environmental problem areas quite clearly. The raw soil data map in Figure 3 does not convey this information.

#### COMPUTER OVERLAYS

The use of overlays in environmental planning was popularized by McHarg in the 1960's.<sup>(1)</sup> In McHarg's view the physical attributes of a parcel of land determine the best use of that land. In McHarg's

---

\*These sensitivity classes were selected for illustrative purposes only.

technique "the environment" is first broken down into various components (such as the variables used for this study). Each component is considered separately with each feature assigned to one of a number of environmental sensitivity classes in the way described above. For each variable a clear acetate overlay is prepared with shadings ranging from light to dark assigned to areas of increasing environmental sensitivity. The overlays are combined to produce a composite map of environmental sensitivity in the study area.

Computer routines have been developed to overlay a series of computer made maps. For this study a computer program called OVERLAY was used in conjunction with SYMAP to combine the soils, historic sites, land use, and road system maps. The environmental features in each of these maps were assigned to one of the three sensitivity classes defined in the previous section of the report. SYMAP versions of these maps\* were produced (see Figures 9-11) and stored in machine language format. The program OVERLAY was called on to successively combine the stored maps in overlay fashion. Figures 12-15 exhibit the overlay sequence beginning with the soil map and proceeding with successive overlays of the historic sites, land use, and road system environmental sensitivity maps. The result (Figure 15) is a composite environmental sensitivity map of the study area.

As with the computer made maps of the individual variables, the composite sensitivity map can be manipulated by making adjustments to any or all of the underlying component maps. For example, if errors had been detected in the soil environmental sensitivity map (Figure 8) and instead the map should appear as in Figure 16, then a new composite overlay map could be produced (Figure 17) which would reflect this change.

---

\*Because of the nature of the data in the road system map, an environmental sensitivity map of this variable has no meaning. The road system map is included because it is an excellent example of line data and is closely related with transportation planning.

## CONCLUSIONS AND RECOMMENDATIONS

As shown in this report, computer mapping techniques, even though they are relatively new developments, are quite sophisticated and have many applications in transportation planning. Among those applications not explicitly mentioned in this report are the use of computer maps to disseminate environmental information at public hearings using a remote cathode-ray tube device, the production of cross-sectional and three-dimensional views of environmental data, the use of weightings in the overlay procedure to give emphasis to the greater importance of certain variables over others in the corridor selection process, and the possibility of developing a summary environmental impact statement supported by computer maps and an environmental data bank.

The obstacles to the implementation of computer mapping techniques for use by the Environmental Quality Division lie not in a lack of applications or in the limitations of the software and hardware, rather they lie in the costs of developing a useful environmental data bank. The focus of future computer graphics studies will be on issues such as:

1. What data items are required by the Environmental Quality Division?
2. Where can these data be obtained and at what cost?
3. Are these data of sufficient quality relative to their cost?
4. How long would it take to collect this information and implement a working computerized data bank?
5. Should the data be initially collected for some areas of the state and not others, or should they be collected statewide?
6. How much information will have to be collected in the field by Department personnel?

Since SYMAP has been presented only as an example of the state of the art of computer mapping techniques, other computer programs should be obtained and evaluated. An appraisal should be made of the strengths and weaknesses of these programs with emphasis on their run time costs and the usefulness of their output to the Environmental Quality Division.

Computer cartography is a rapidly advancing field and appears to be gaining support at a number of local, state, and federal agencies. In the state of Virginia alone the city of Virginia Beach and the Richmond Regional Planning District have implemented computerized information storage and retrieval systems which employ computer mapping to some extent. Giles et al. at Virginia Polytechnic Institute and State University have developed a computerized corridor selection system (POWER) using a data bank called the Statewide Information System. The Census Bureau and the United States Geological Survey have used computer mapping extensively with geocoded demographic and land use data banks. The development and growth of these information systems suggest that they are practical and economically feasible. Further, the Department may one day be able to tap into these data banks and use the information stored in them.

Computer cartography offers the Department a promising way to collect, store, and display environmental data. Many questions need to be answered and many issues need to be resolved. However, the potential benefits of computer mapping appear to be great and worth pursuing.



## REFERENCES

1. McHarg, Ian L., Design with Nature, Doubleday/Natural History Press, Doubleday and Co., Inc., Garden City, N. Y., 1969.





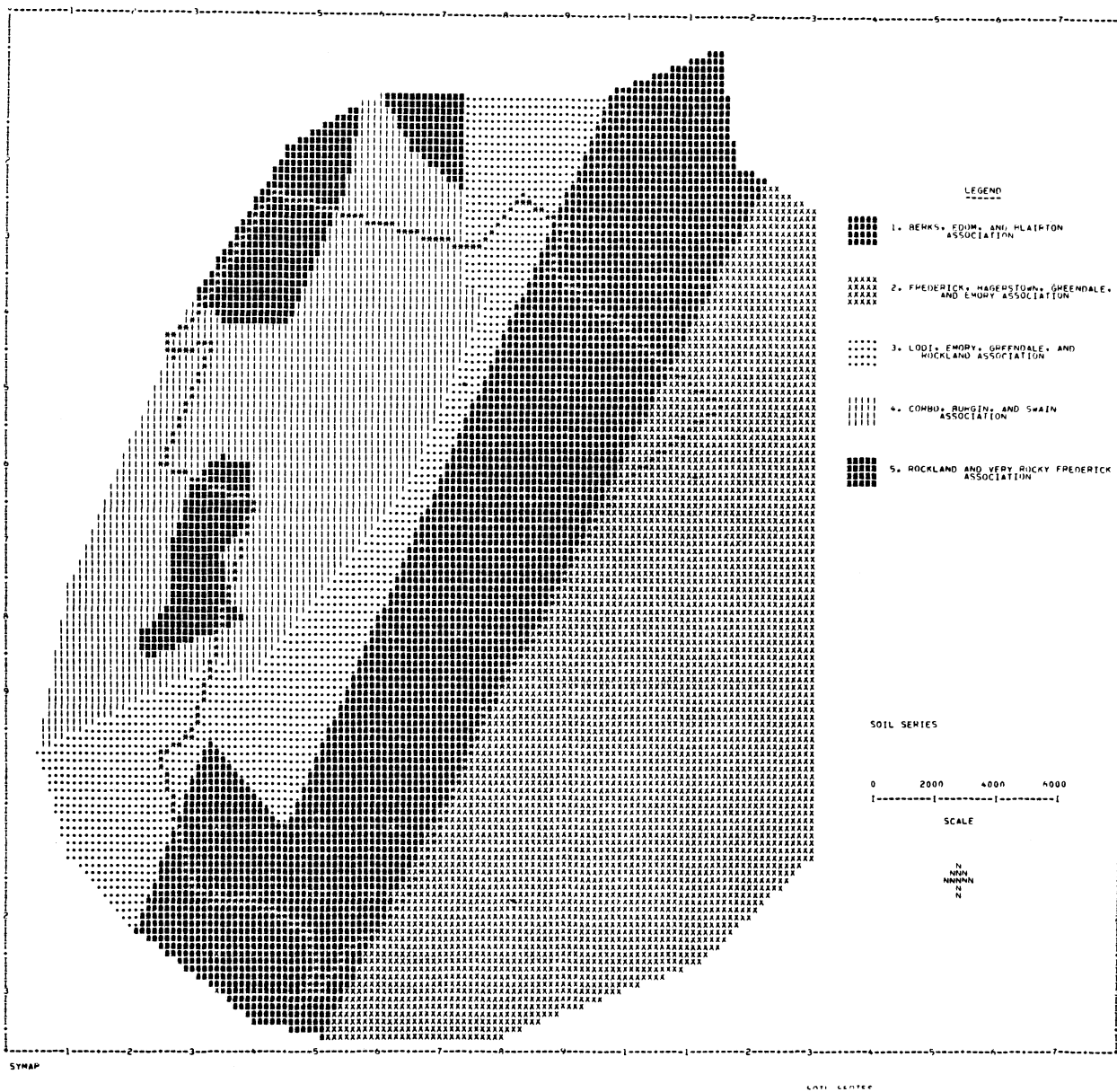


Figure 1. SYMAP produced soil association map, Winchester, Va.

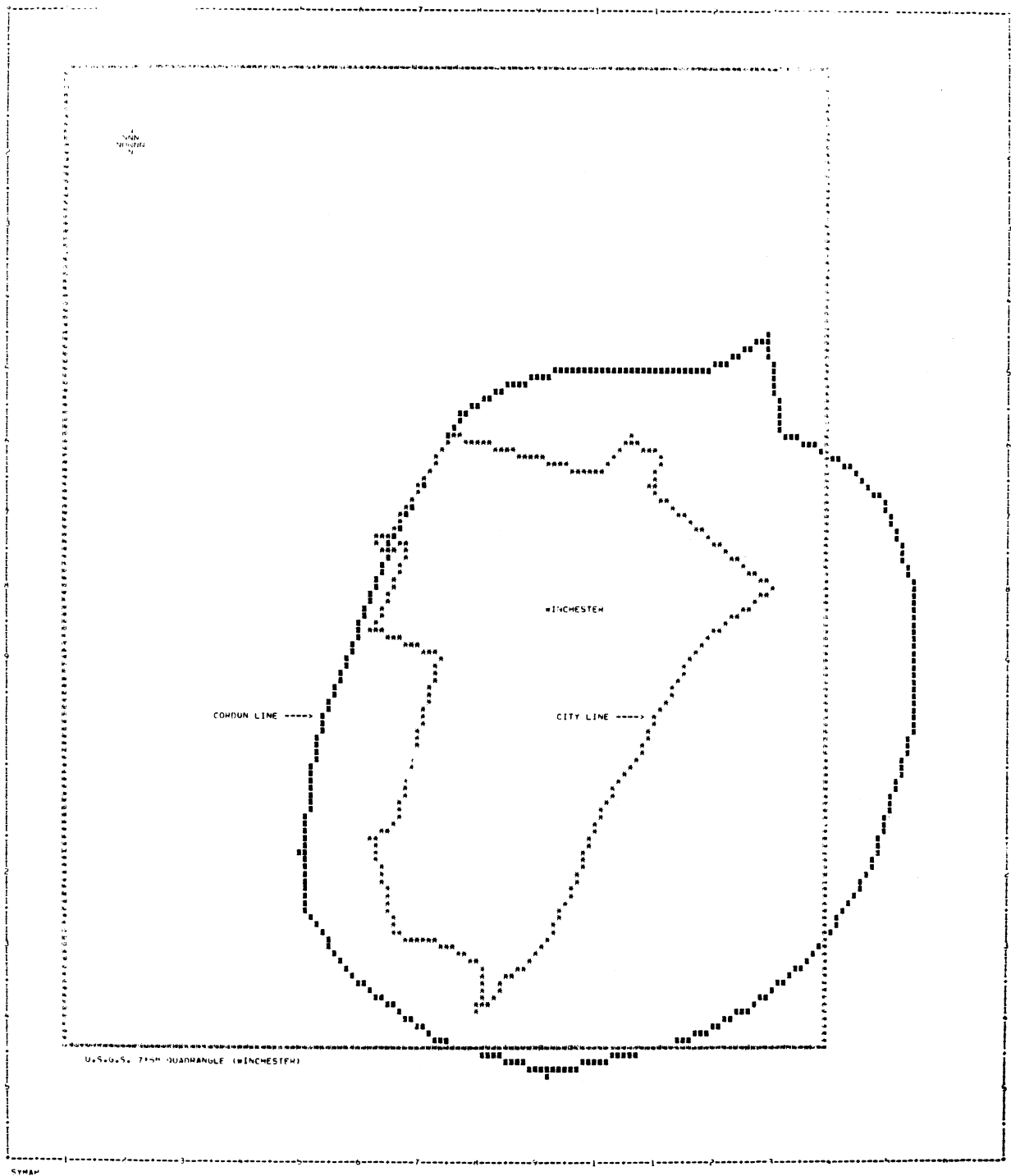


Figure 2. SYMAP produced study area map, Winchester, Va.

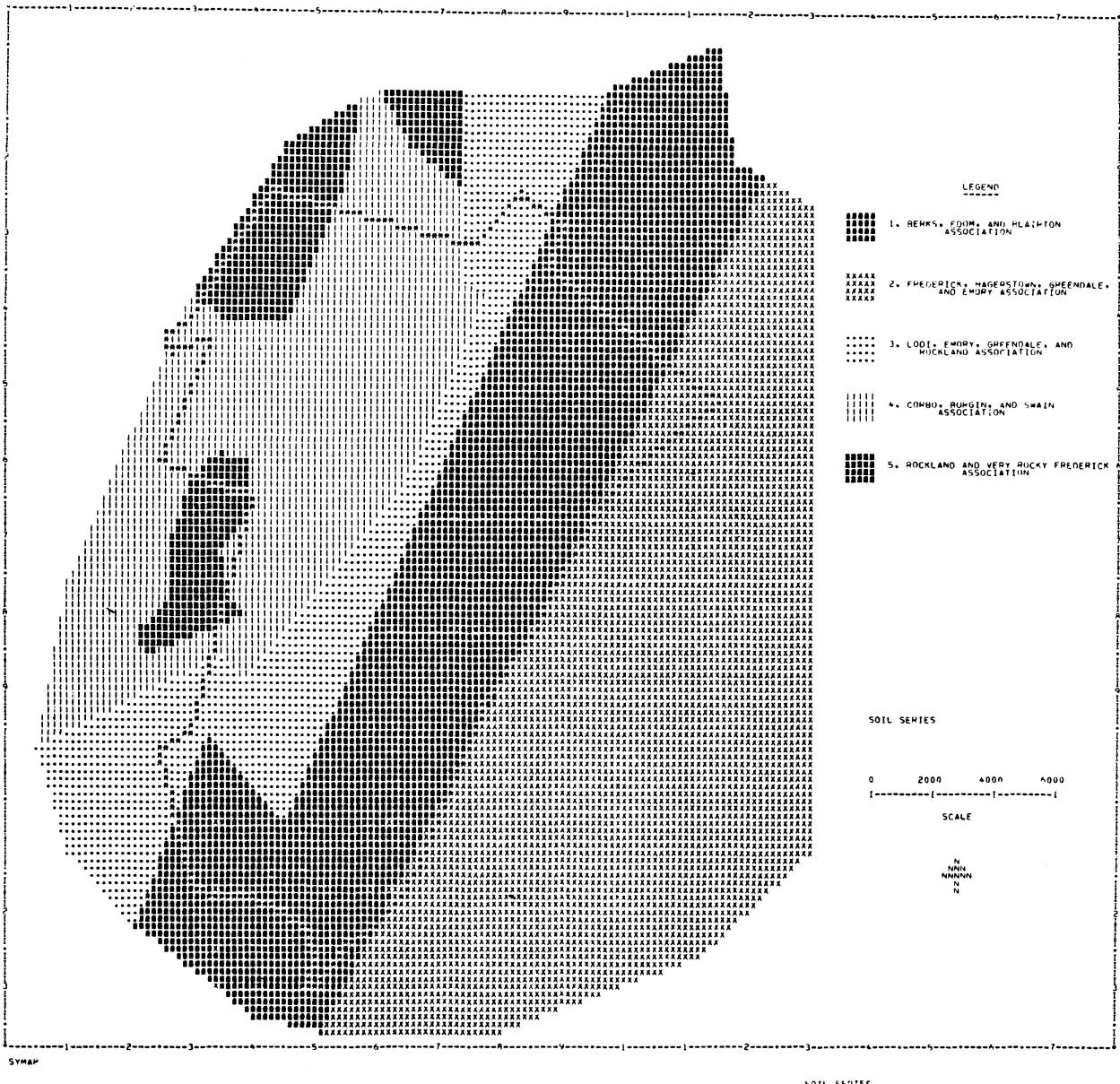


Figure 3. SYMAP produced soil association map, Winchester, Va.

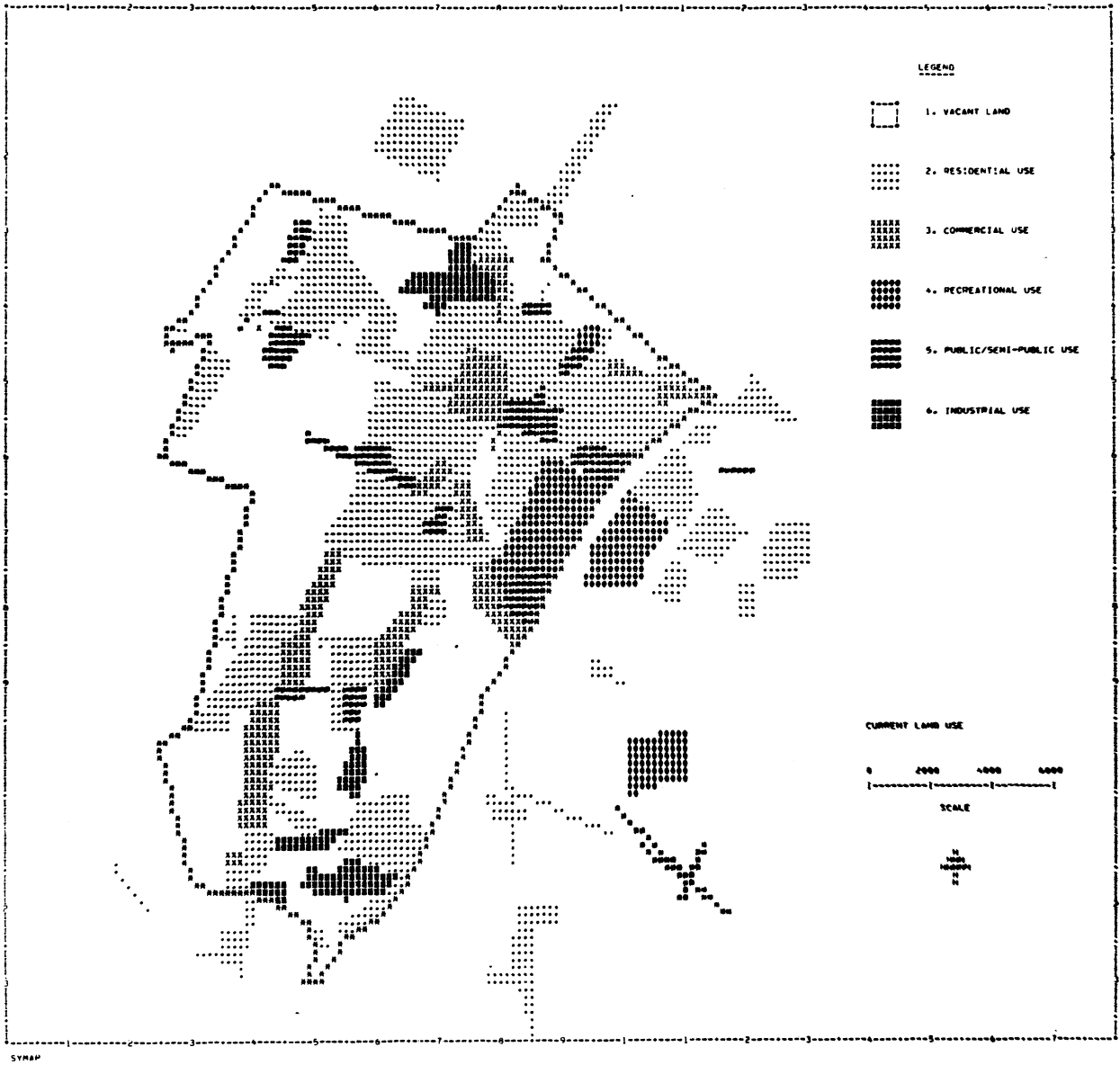


Figure 4. SYMAP produced land use map, Winchester, Va.

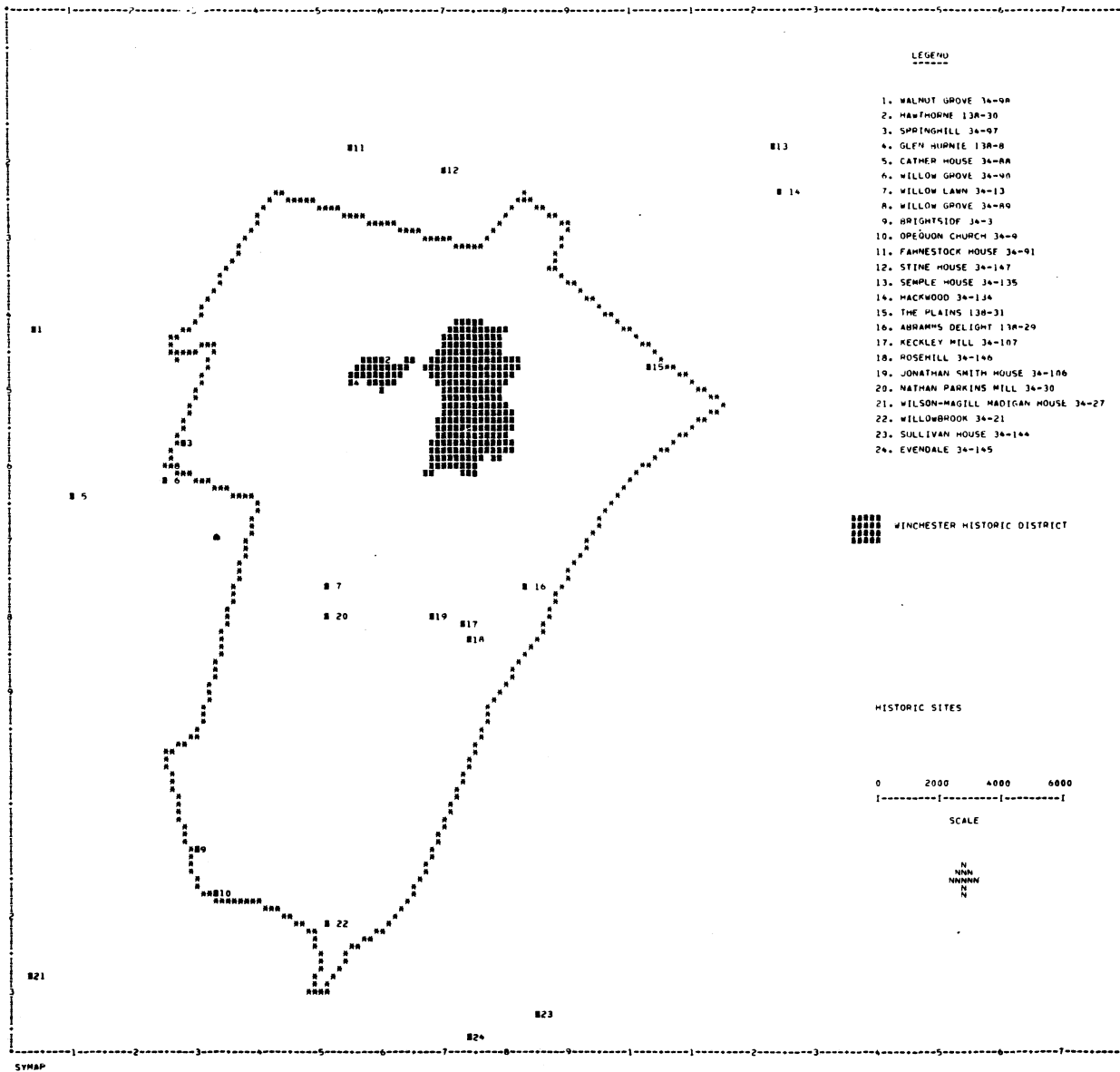


Figure 5. SYMAP produced historic sites map, Winchester, Va.

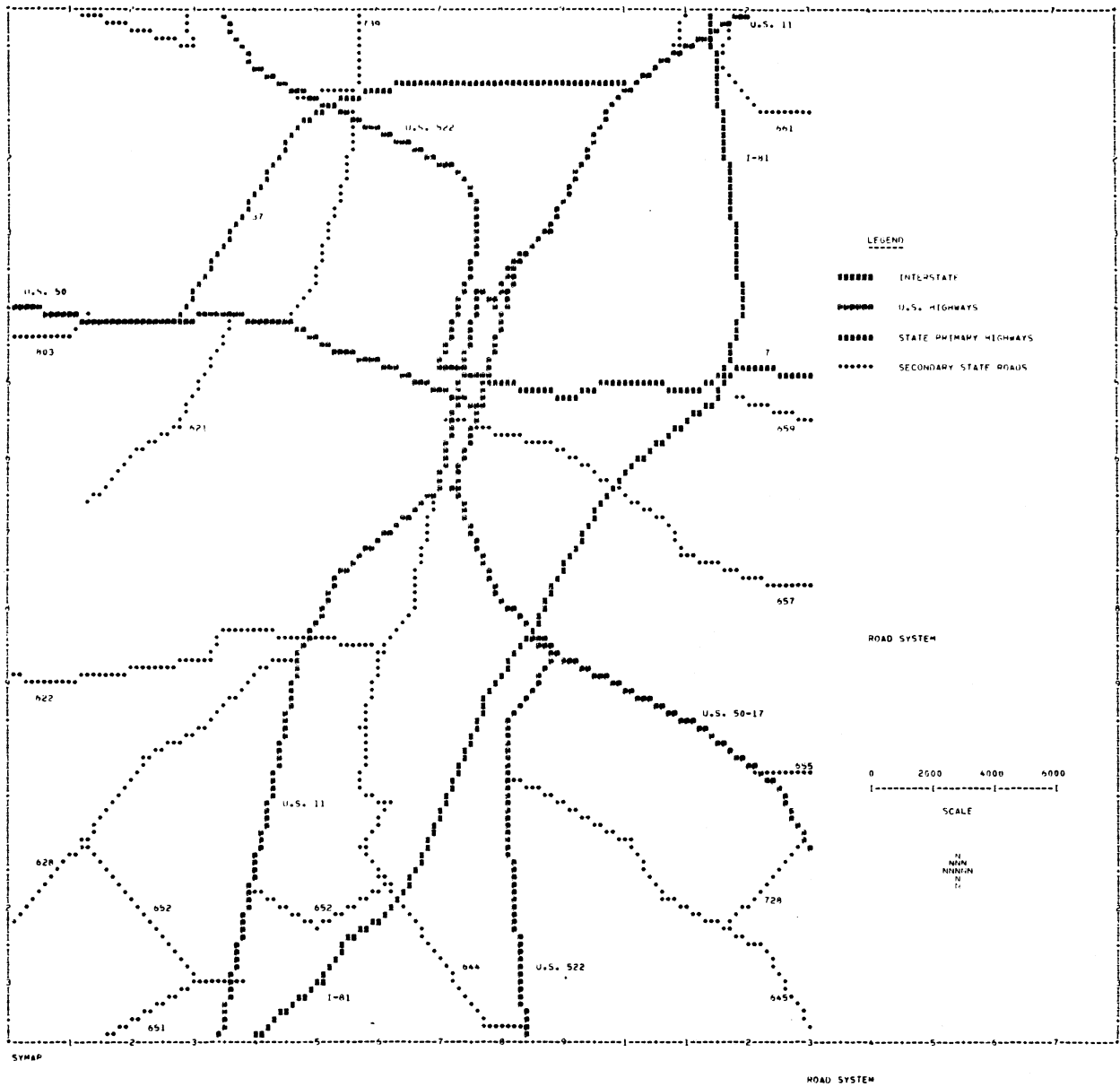


Figure 6. SYMAP produced road system map, Winchester, Va.

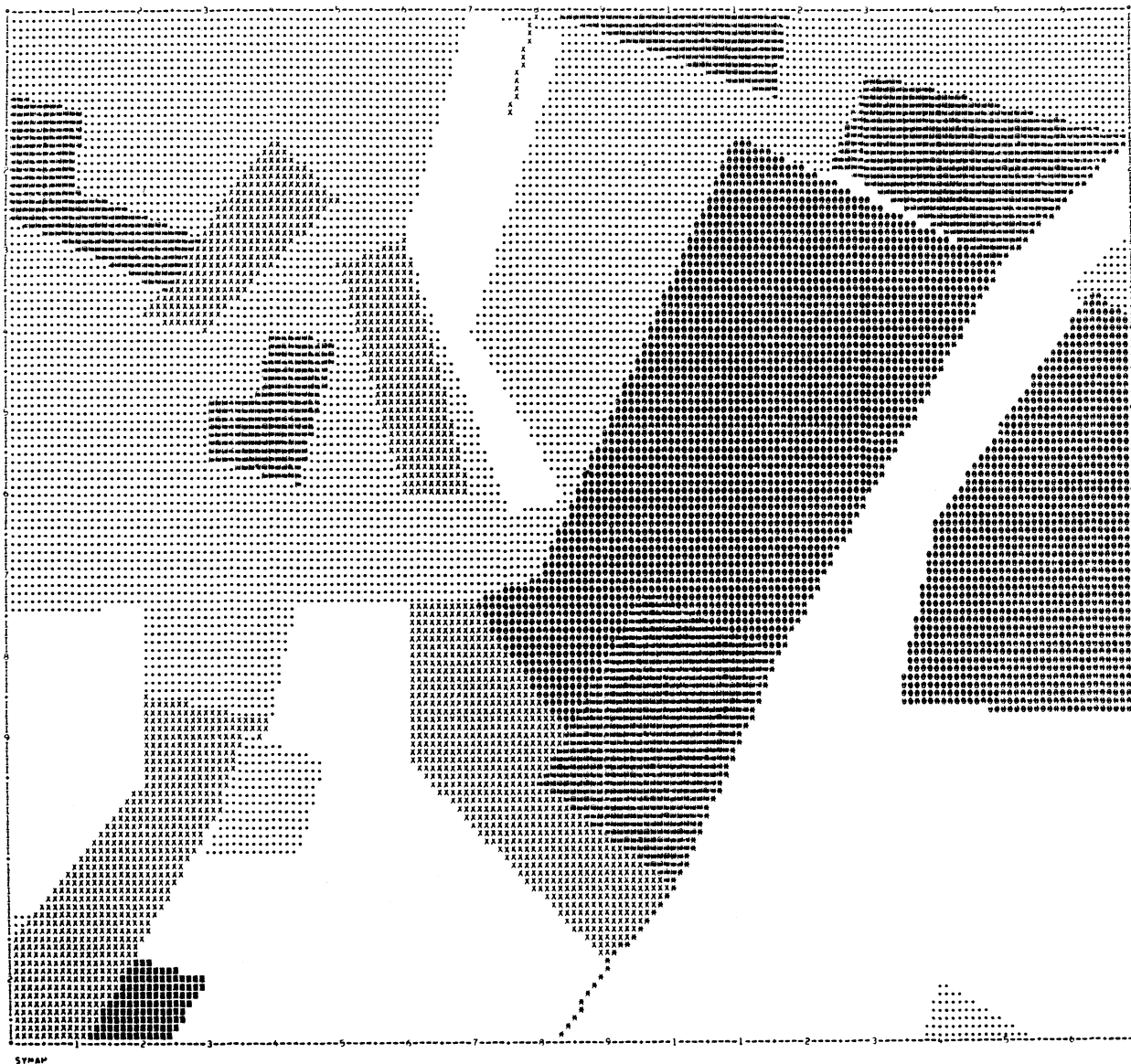


Figure 7. SYMAP produced blowup of portion of land use map, Winchester, Va.

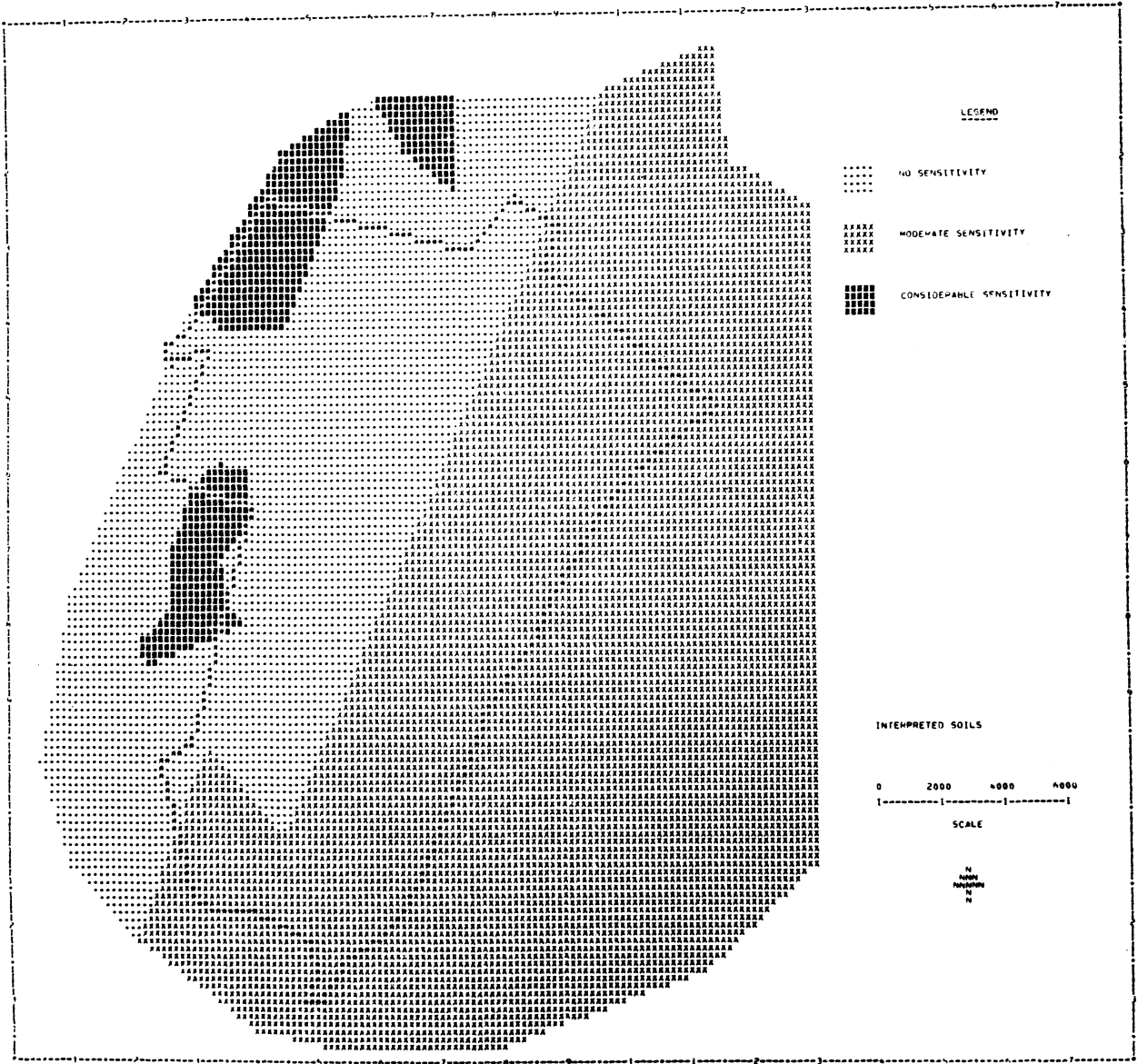


Figure 8. SYMAP produced soil environmental sensitivity map, Winchester, Va.



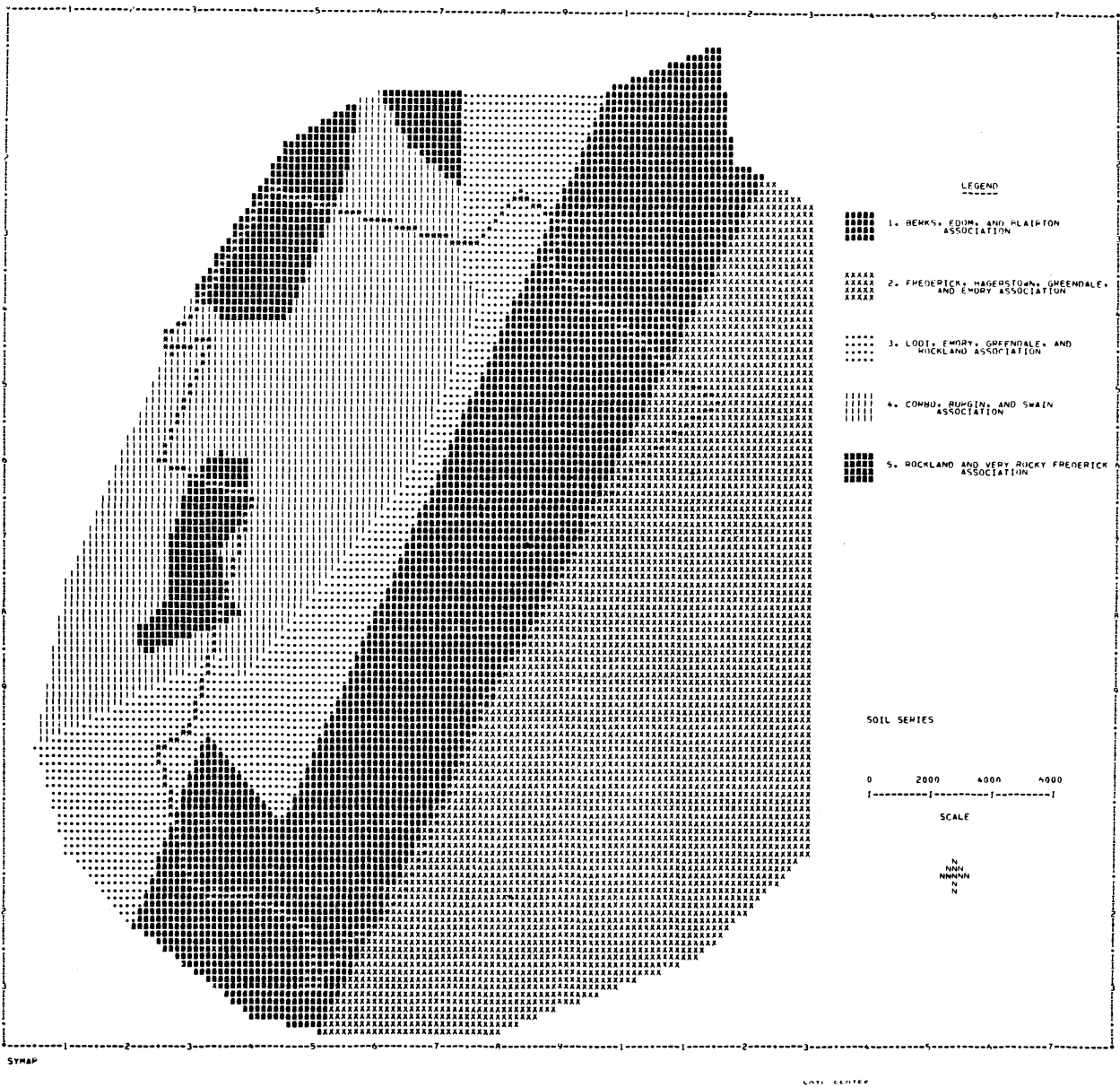


Figure 3. SYMAP produced soil association map, Winchester, Va.

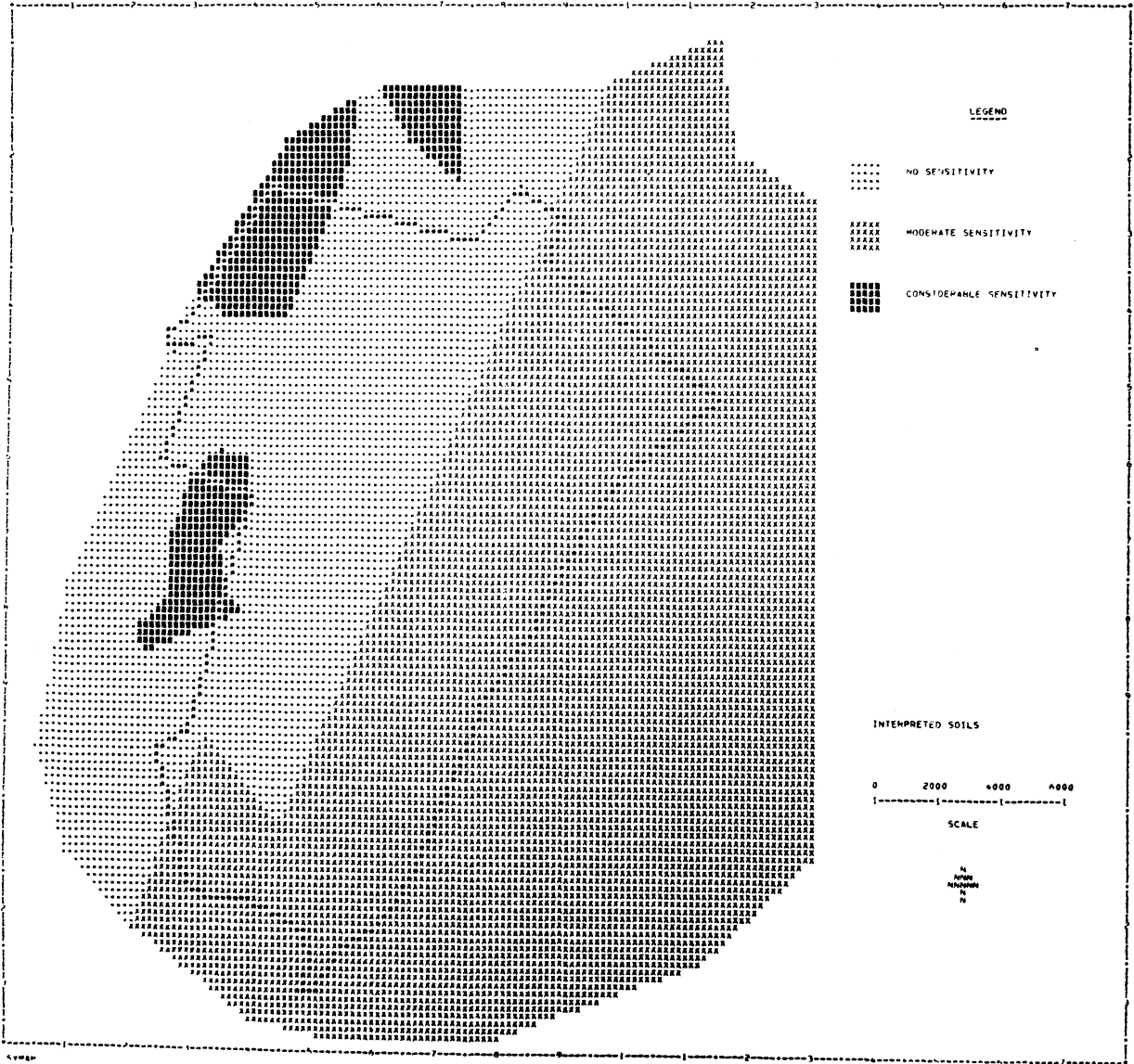


Figure 9. SYMAP produced soil environmental sensitivity map, Winchester, Va.

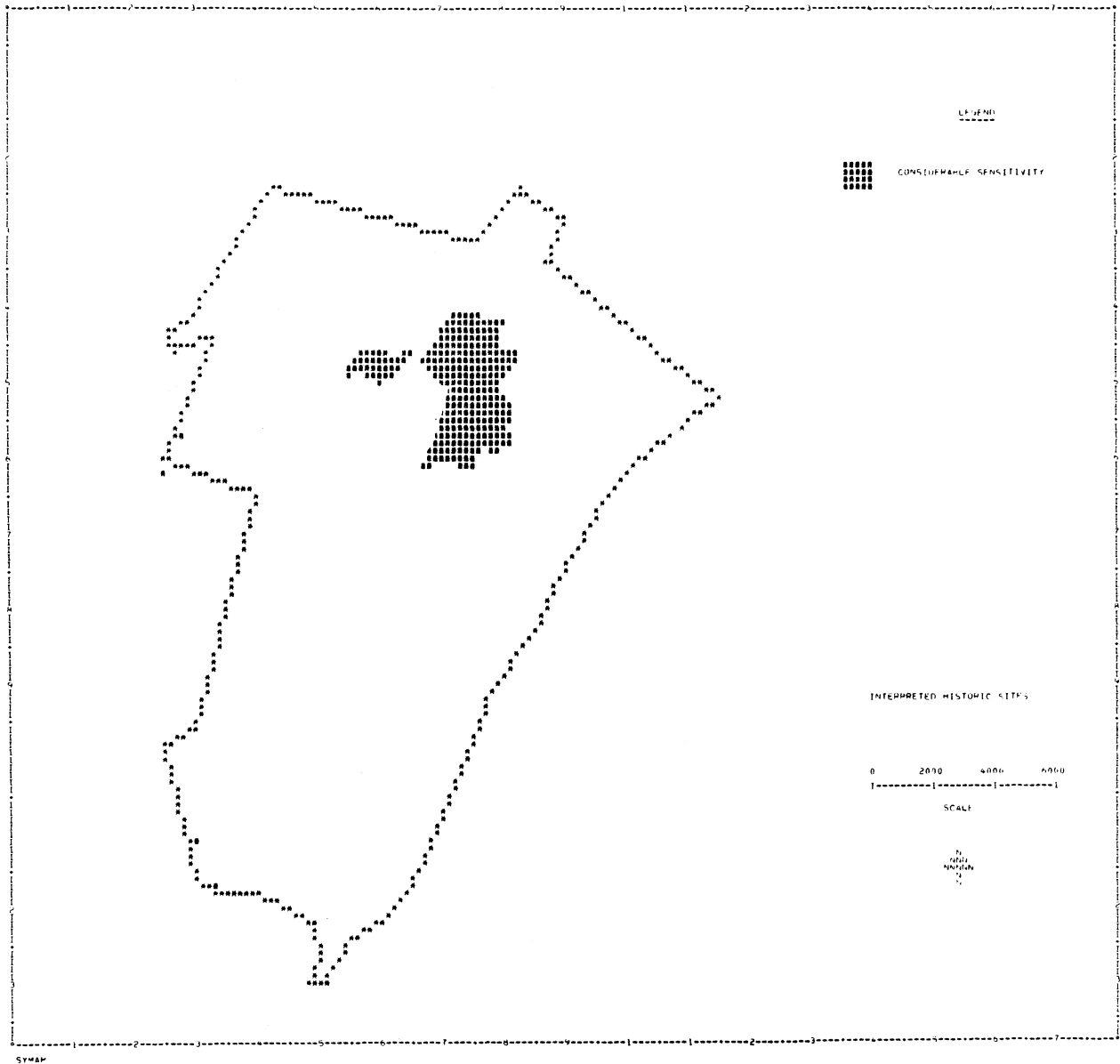


Figure 10. SYMAP produced historic sites environmental sensitivity map, Winchester, Va.



Figure 11. SYMAP produced land use environmental sensitivity map, Winchester, Va.

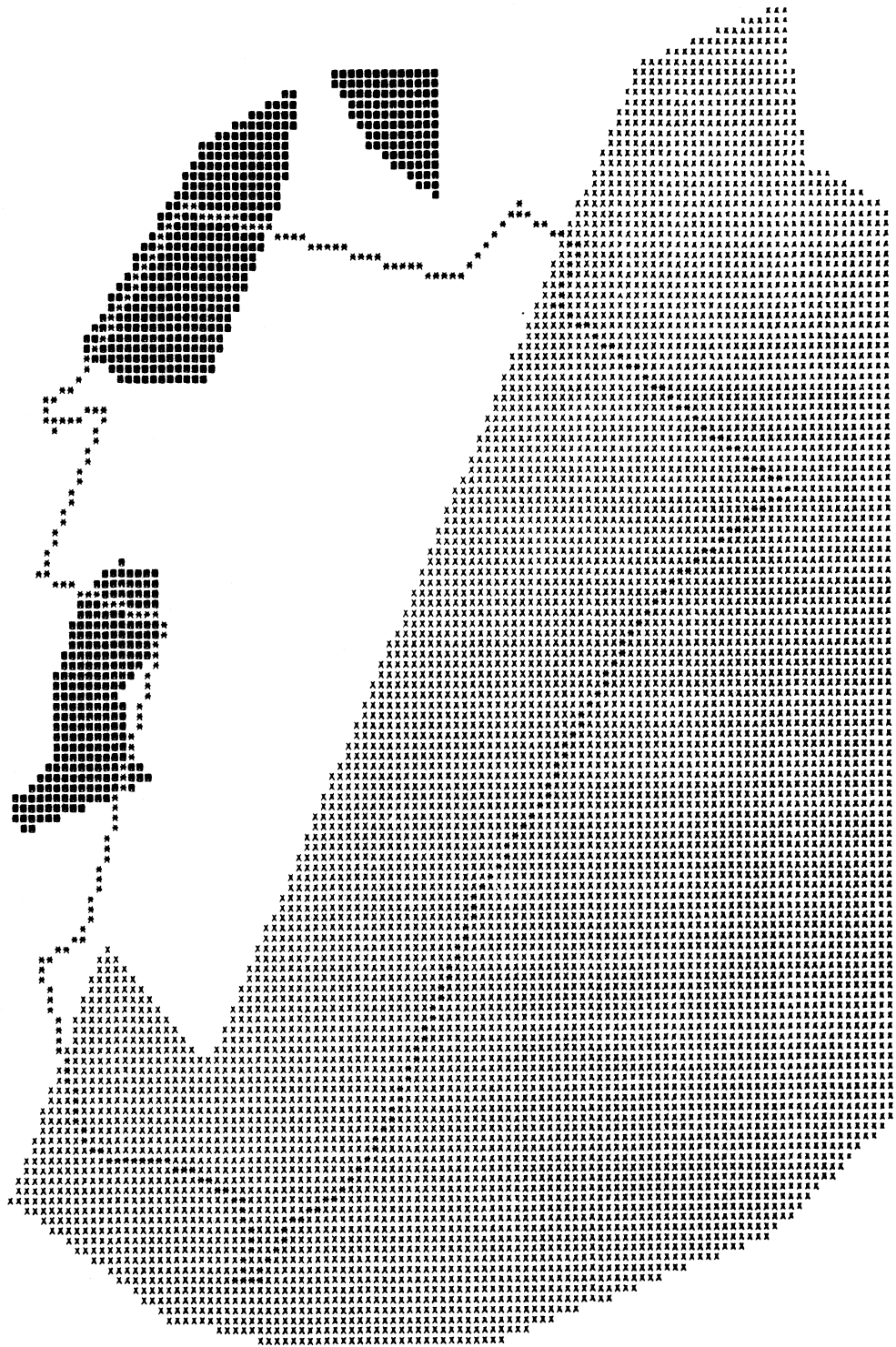


Figure 12. OVERLAY produced soil environmental sensitivity map, Winchester, Va.

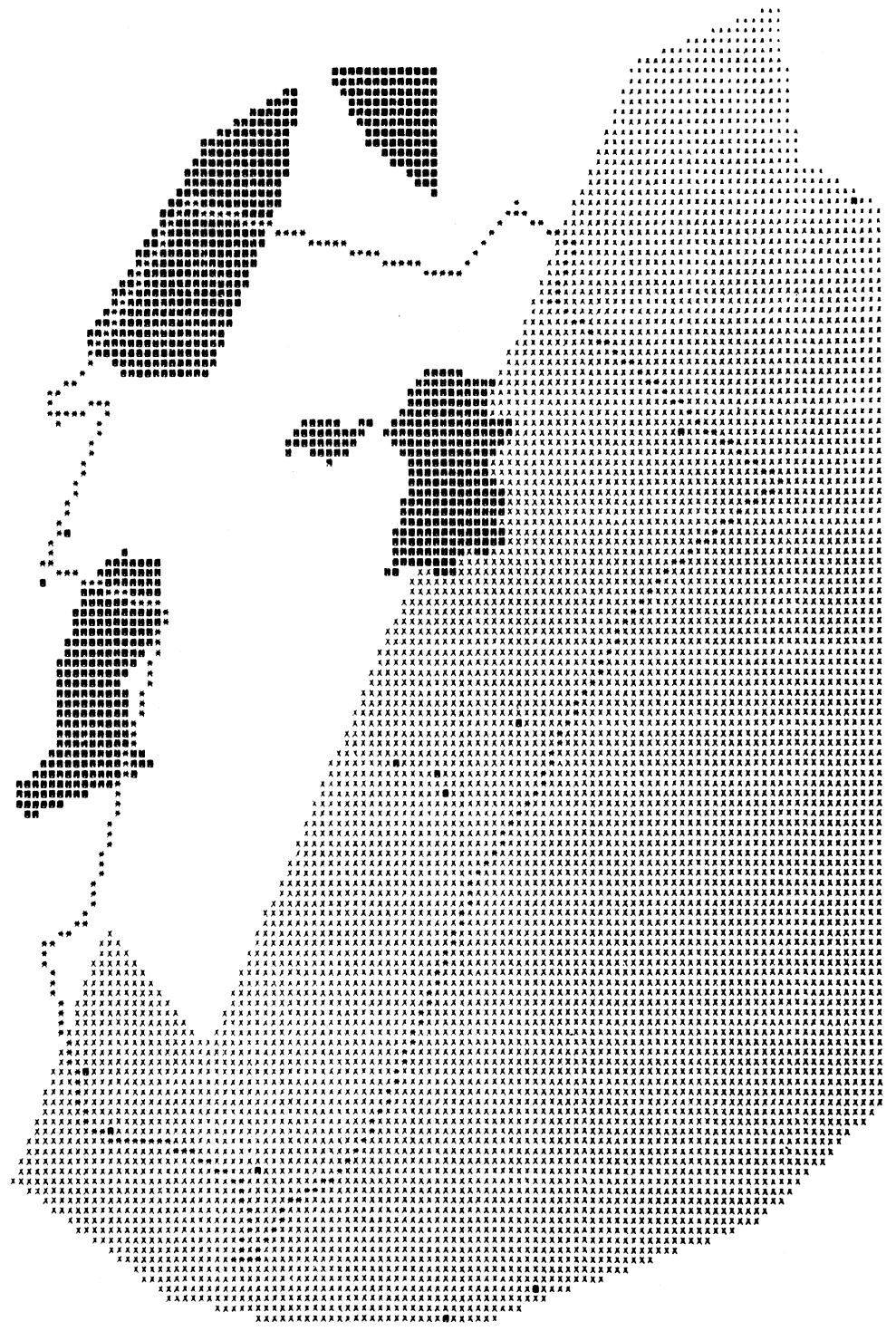


Figure 13. OVERLAY produced composite of soil and historic sites environmental sensitivity maps, Winchester, Va.

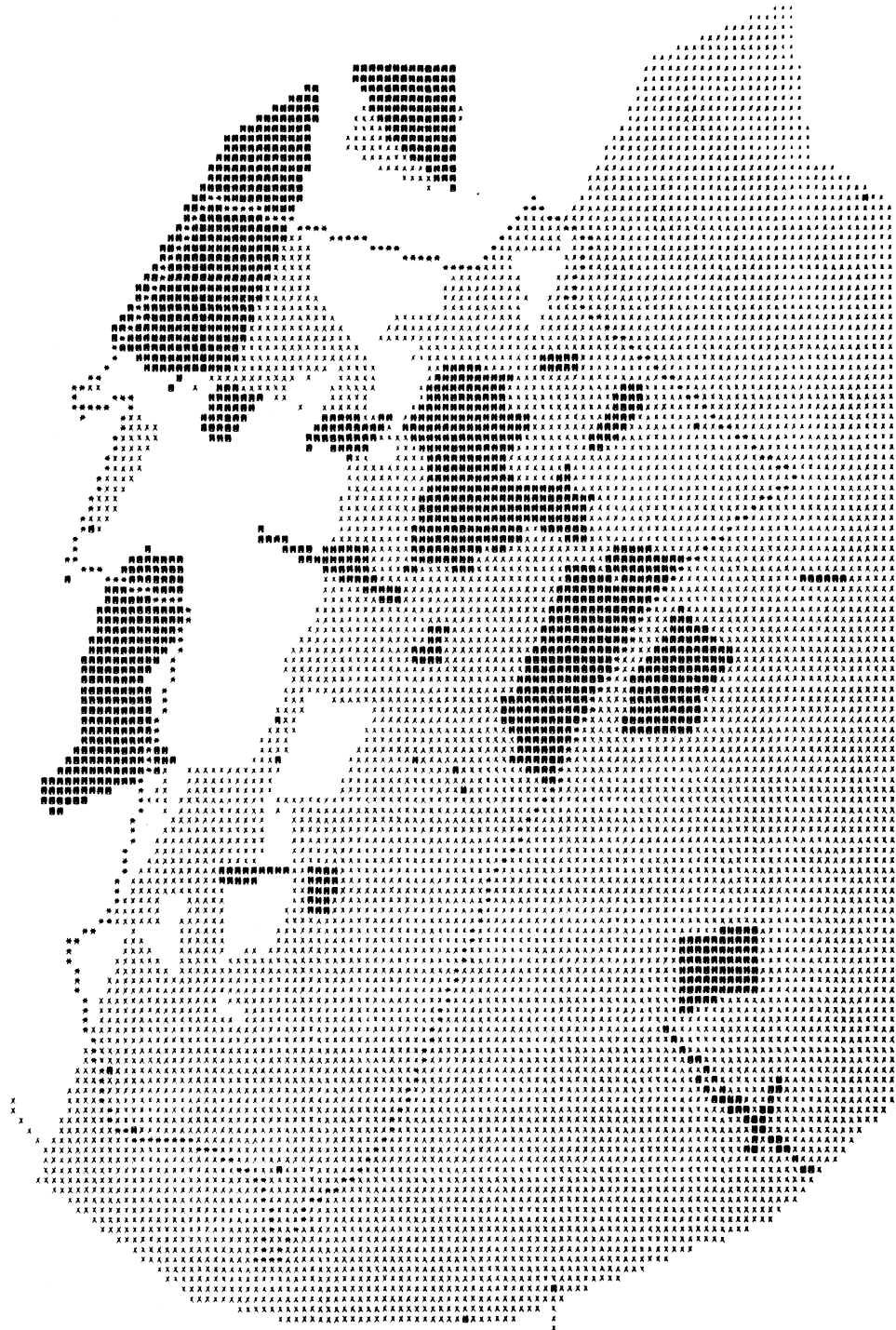


Figure 14. OVERLAY produced composite of soil, historic sites and land use environmental sensitivity maps, Winchester, Va.

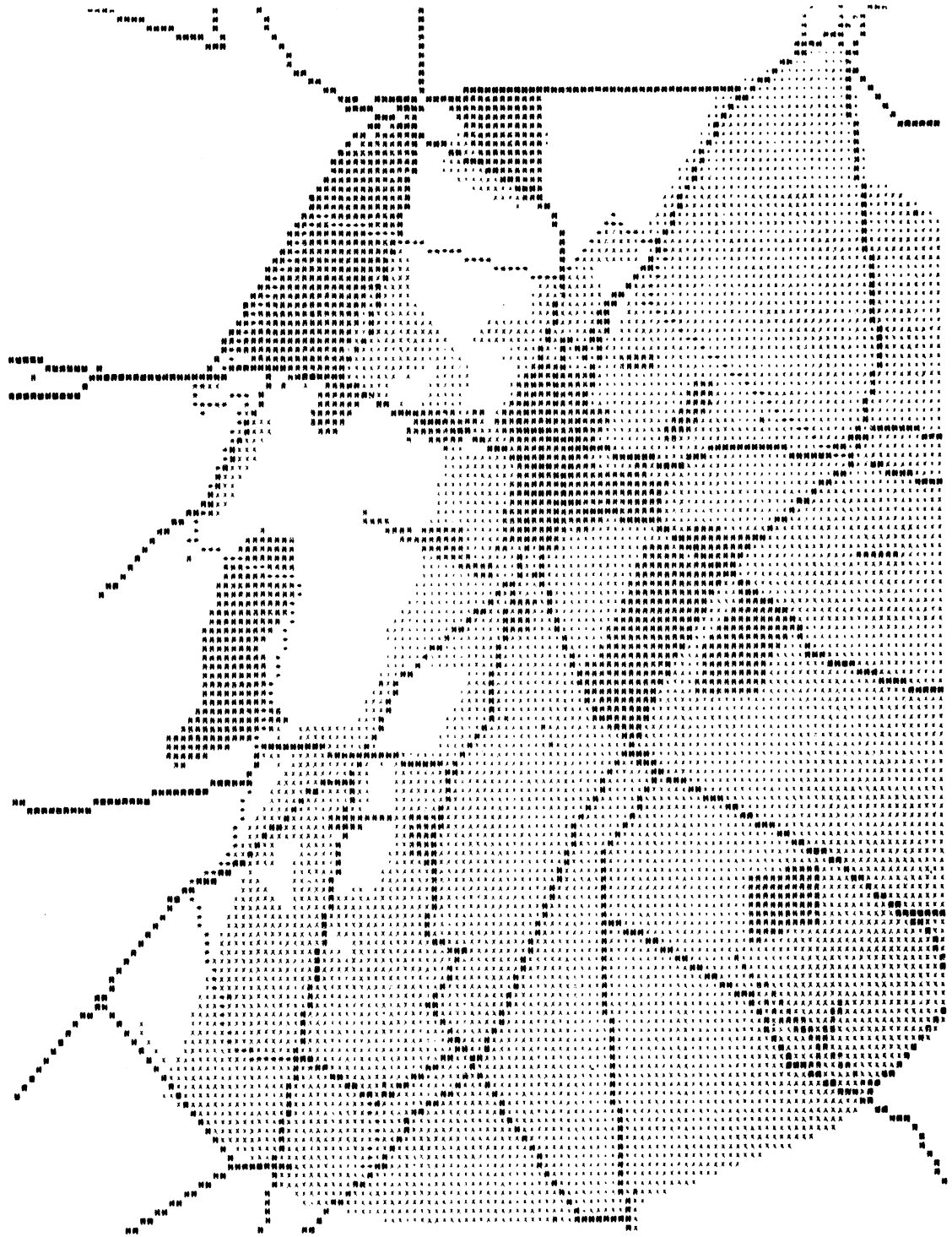


Figure 15. OVERLAY produced composite of soil, historic sites, land use, and road system environmental sensitivity maps, Winchester, Va.



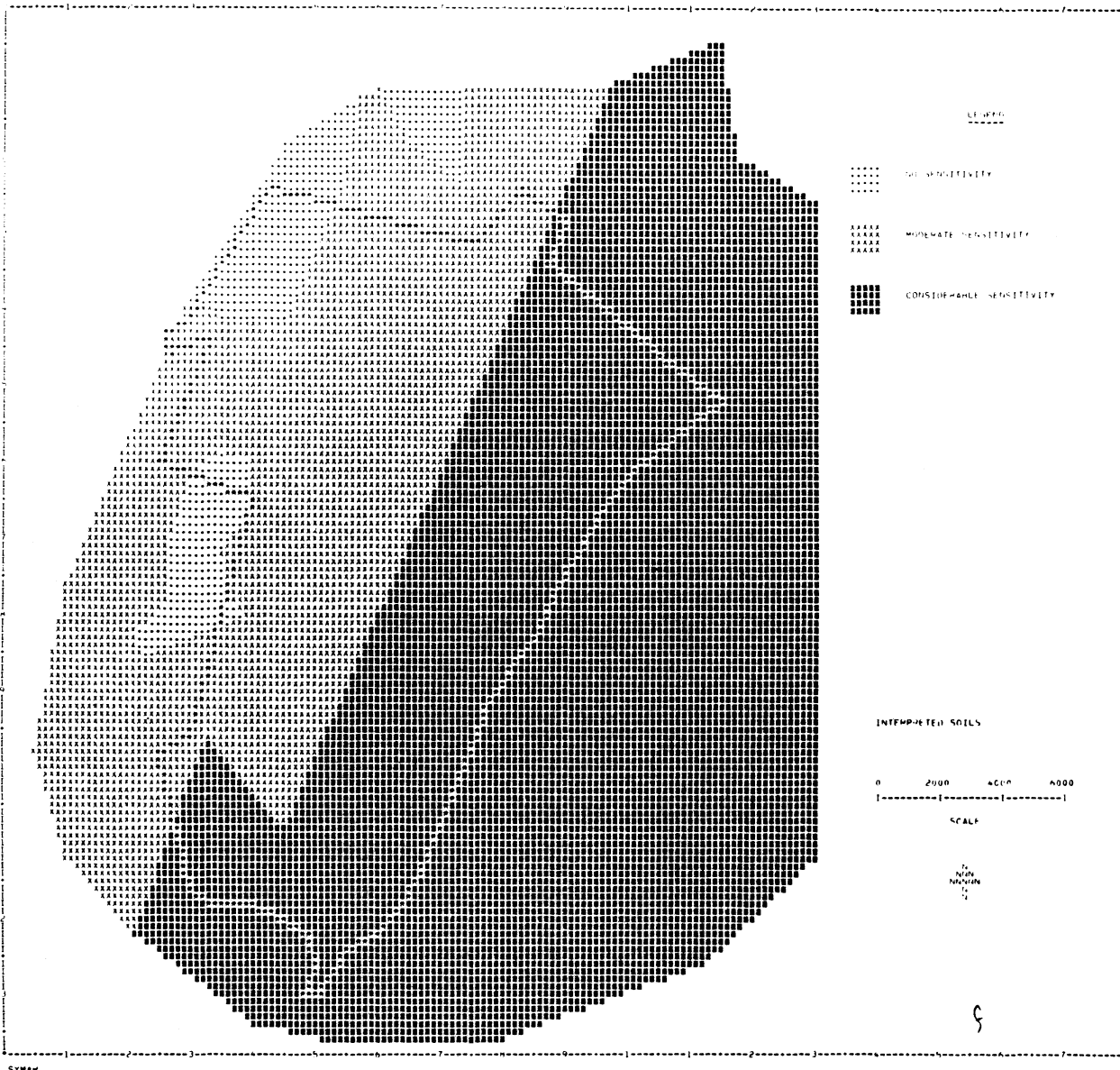


Figure 16. SYMAP produced reevaluated soil environmental sensitivity map, Winchester, Va.

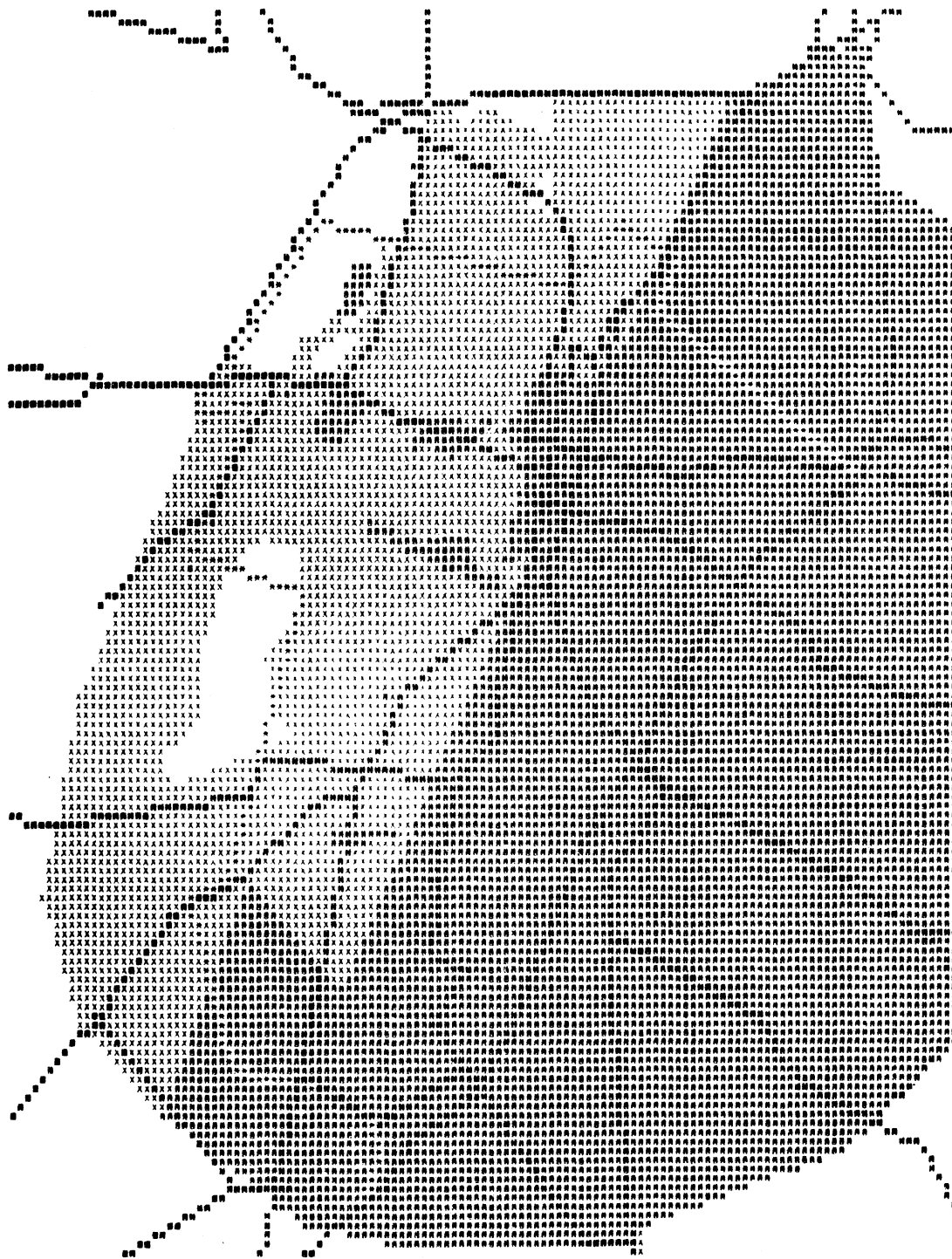


Figure 17. OVERLAY produced composite of reevaluated soil, historic sites, land use and road system environmental sensitivity maps, Winchester, Va.