EXPERIENCES WITH THE USE OF A DESKTOP GIS FOR ANALYSIS OF SELECTED WATER RESOURCE PROBLEMS

Kathy N. Watts, Research Associate
and **David H. Moreau**, Director
Water Resources Research Institute of the
University of North Carolina

The purpose of this paper is to report on our recent experience with the use of a desktop GIS system and related data sets for the analysis of selected water resource problems. Four different problems are discussed, all of interest to state and local governments in North Carolina. They are:

1) evaluating the impacts of North Carolina's proposed regulations for protecting water sheds for public water supplies;

2) counting housing units and population served by geographic areas in a study of urban water conservation;

3) estimating spatial patterns of water use for the analysis of a water distribution system;

4) preparation of watershed management plans for a regional water supply.

Among the principal data sets used for addressing these problems were the TIGER/Line Precensus Files, datapoint files for the P.L. 94-171 census data for 1990, and water utility customer files.

This paper briefly describes each of the problems, methods and data sets used for analysis, and any significant difficulties or limitations encountered in the process. A few general conclusions about desktop GIS and the datasets are also offered.

The Water Resources Research Institute of the University of North Carolina (WRRI-UNC) has been exploring the use of mapping and GIS software for several years. A number of very useful products are on the market, but the Institute chose to limit its choices to those that satisfied the following criteria:

1) the software must be capable of performing certain basic operations for the analysis of geographic information;

2) extensive training in computer software is not necessary for a computer literate person;

3) the software must be able to import and export geographic and data files in a format that is readily adaptable to other software; and

4) it must operate on a general purpose per sonal computer and be priced at no more than $5,000.

The experience reported here is based on the use of Atlas GIS, a software package that satisfies the above criteria. Other packages may be equally powerful and competitively priced; this report does not constitute an endorsement of a particular product. Experiences cited here are based on the use of an IBM AT upgraded to a 4 MB of RAM, a 386 SX chip and a memory manager.

Applications

Analysis of Watershed Protection Policy

In 1989, the legislature of North Carolina passed the Watershed Protection Act to limit urban encroachment on watersheds that drain to public water supplies. Rules adopted pursuant to that legislation provided for density and impervious surface limitations within water supply watersheds. Four classes of watersheds were proposed in the rules where each watershed was to be classified largely on the basis of existing residential densities. Among the issues raised in the public debate over the rules was: would the rules put the brakes on home building and economic growth due to limits on the supply of land? WRRI undertook a study to address this issue. Development densities were calculated for each of the 415 designated water supply watersheds. Those densities were then compared to densities permitted by the rules.

Existing development densities were found through basic GIS operations on pre-existing digital data sets. A digital file of polygonal representations of watershed boundaries was purchased from the N.C. Center for Geographic Information and Analysis (NCCGIA). The geographic file of watershed boundaries was in ARCINFO export format in N.C. State Plane coordinates. The watershed polygon files were about 5 MB. Atlas GIS allows the user to convert files into other coordinate systems, and that feature was used to convert the coordinates of the polygons to latitude and longitude to match the data file described below.

A file of block level 1990 census data for the state was obtained from the Institute for Research in Social Science, University of North Carolina at Chapel Hill. The data file contained 1990 counts of housing and population and the latitude and longitude of the centroid of the approximately 225,000 census blocks in North Carolina. ASCII files that contained this data were quite large, about 12 MB. Data was moved from one machine to another on 3.5-inch diskettes, using BACKUP and RESTORE commands.

A standard point in polygon operation was used to total the population and housing within each of the 415 watersheds as illustrated in Figure 1 for selected counties. Areas of polygons are automatically calculated by Atlas GIS, and all attributes can be manipulated using any dBase III+ compatible expression. Areas were converted into appropriate units and divided into housing and population totals to produce existing housing densities. A similar operation was used to find population and housing densities over counties using a grid of 1.0-square-mile cells.

In a separate operation, an attempt was made to estimate that portion of each county that was covered by each of the four classes of watersheds. A digital boundary file for the 100 counties in North Carolina was obtained from NCCGIA. The operation of splitting the 100-county layer with the watershed layer proved to be too complex a task for the software. Selected counties were split one at a time by the watershed layer.

Results showed that with the proposed densities, there was not a significant constraint on the supply of land for development. In fact, without the density bonuses that the rules tied to use of stormwater controls, the watersheds could hold more than three times the population of North Carolina.

Water Conservation

The desktop GIS also proved to be of value in a study of water conservation in Durham, N.C. Two particular needs in that study were well-satisfied through use of GIS. First, like most water and sewer utilities, the city of Durham has very good records on customers, but the customer records do not include information about the number of people, not even the number of housing units that are served by a given meter. Information of that kind is essential to any evaluation of water use. For Durham these numbers were found in a manner similar to that described previously. Block-level census counts for housing and population in 1990 were captured for the Durham service area using the point-in-polygon operation.

That study also included an examination of potential reductions in capital investments in wastewater treatment facilities that might result from water conservation and elimination of excess inflow and infiltration into sewer systems. Baseflow calculations for that analysis required population and housing counts for each of Durham's five sewersheds. A polygon was digitized for each sewershed, and the point in polygon operation was used to total housing and population for all blocks whose centroids fell within each of those polygons. Some of the results are illustrated in Figure 2.

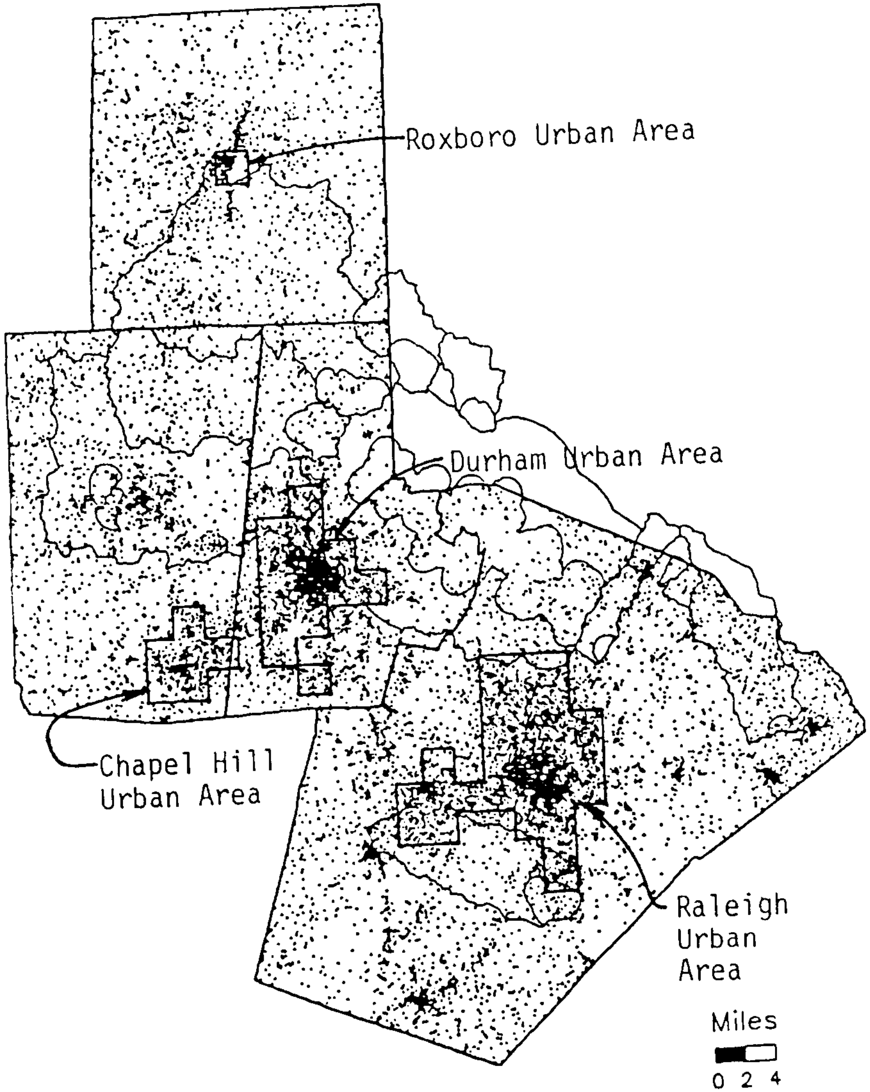


Figure 1-a. Centroids for Census Blocks in Selected Counties and Watersheds in North Carolina

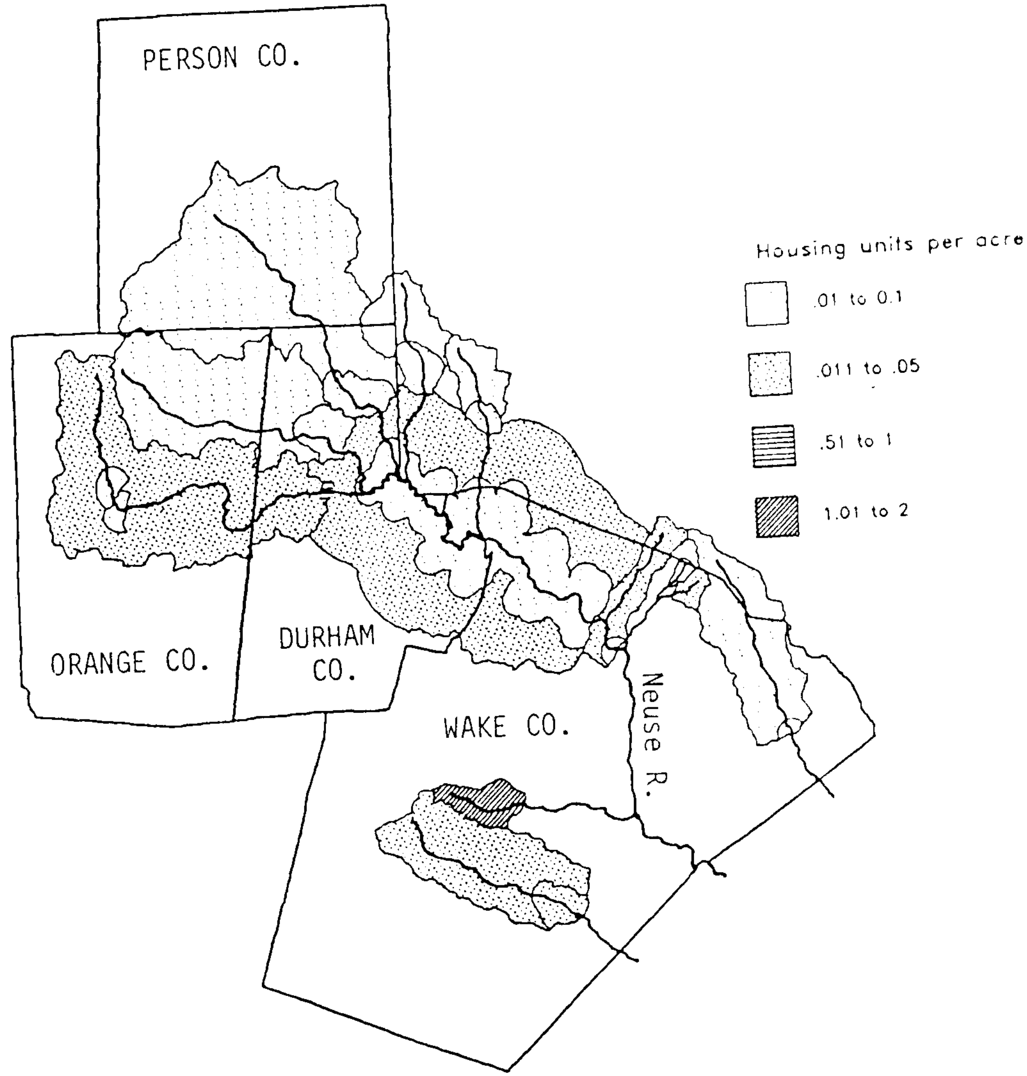
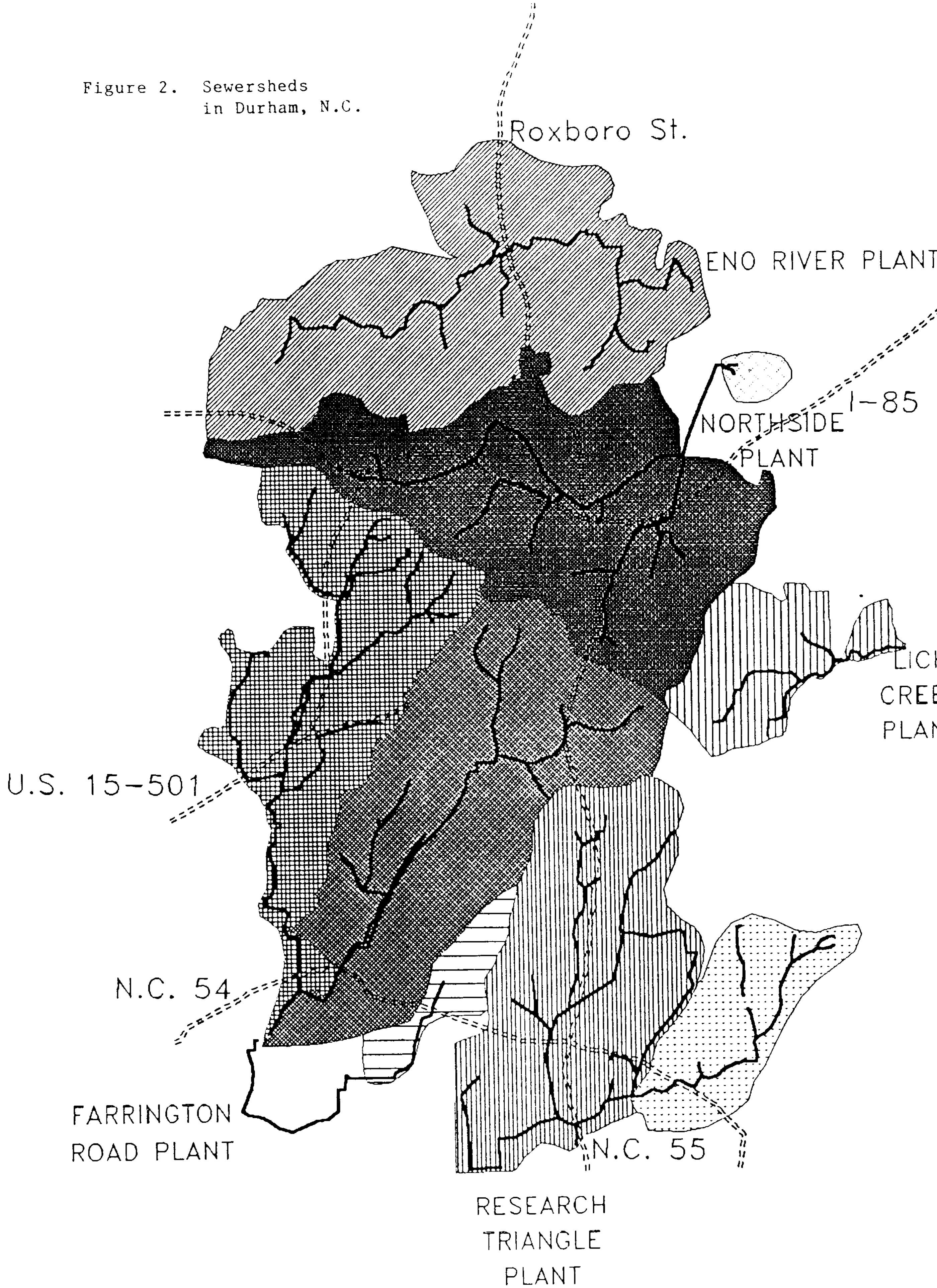


Figure 1-b. Densities of Housing in Selected Watersheds in North Carolina

Figure 2. Sewersheds in Durham, N.C.



Analysis of Water Distribution Systems

A more demanding test of the GIS was undertaken in support of an analysis of a water distribution system for the Orange Water and Sewer Authority (OWASA), which serves Chapel Hill and Carrboro, N.C. This test involved address matching between customer files and TIGER Precensus/Line files. The problem here was to locate each of OWASA's 13,320 customers by latitude and longitude and to aggregate customer records by demand zones.

Customer records contain street addresses, but they do not include location by latitude and longitude. The TIGER files contain geographic information about each street block, including latitude and longitude of beginning and ending points. Segments usually conform to blocks. The OWASA service area included approximately 3,000 such segments.

For cities with populations greater than 50,000, TIGER files include left and right street addresses for the beginning and ending points for each street segment. GIS can use those addresses to match addresses in the customer file, thereby locating customers by street segments. Unfortunately, this area did not meet that population cutoff.

The strategy for overcoming the absence of addresses in the geographic file was two-fold. First, the service area was divided into demand zones with care being taken to minimize the number of streets that crossed the boundaries of those zones. Streets that did not cross those demand zones were assigned minimum and maximum addresses that would cover the range of addresses in the customer file. Second, for those streets that crossed demand zones, boundary addresses were entered manually using a city directory.

Editing the TIGER files is a straightforward process. Those files can be read as random access files. The format for those records are clearly documented in the users manual.

The addresses matching operation proved to be a demanding task. On the first round, only 36 percent of the 13,000 customers were matched by addresses in the TIGER files. Mismatches were caused in large part by different spellings of streets and streets that were not on the TIGER file. A report generated by the GIS that indicates why mismatches occurred proved to be a very useful diagnostic aid. A user-program was also written to create street indexes for the TIGER file and the customer file. A comparison of those two files was also useful as a diagnostic tool.

Once the causes for the mismatches were determined, the second round of address matching resulted in a 72 percent rate of success. The wide variety of causes of mismatches reported out of that process indicated that further matches would have to be made one customer at a time. That was done with the cooperation of OWASA's meter readers.

Matches were found for all but about 100 of OWASA's 13,320 customers, and those accounted for 99.99 percent of water use. After address matching the customers, all the data that was tied to each customer was tied to a geographic location. With those locations it was possible to total annual water use and peak demand. Some of those results are illustrated in Figure 3.

Watershed planning

A fourth developmental GIS project is underway with the preparation of a watershed management plan by OWASA to protect its two surface water supplies. The plan is being developed to guide a land acquisition program and to assess development impacts within those watersheds. The key to that project is the availability of several pertinent datasets that are available in digital form. Layers in the GIS are listed in Table 1.

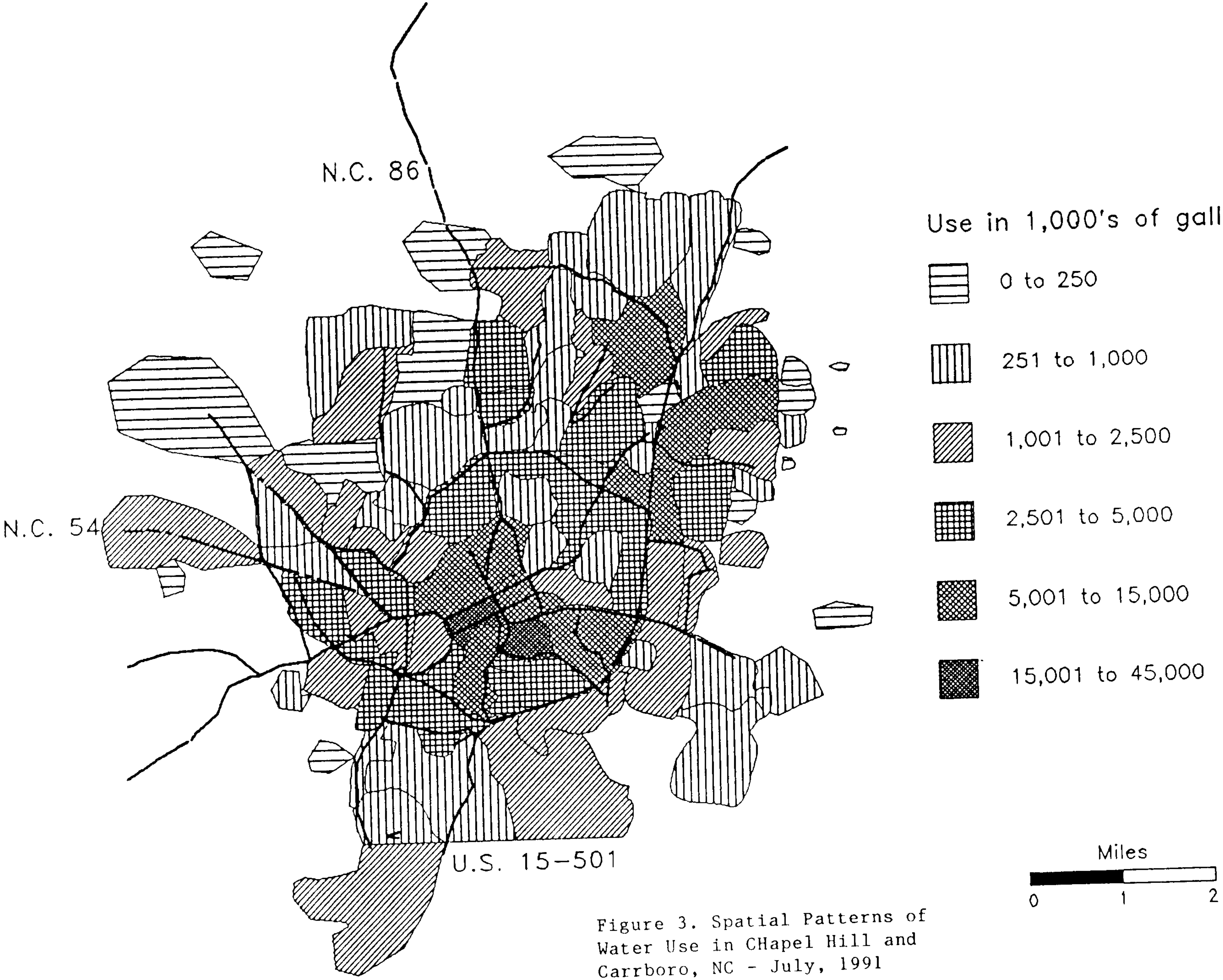


Figure 3. Spatial Patterns of Water Use in CHapel Hill and Carrboro, NC - July, 1991

Table 1. Layers for Watershed Planning Model

Data	Source
Watershed boundaries	NCCGIA (1)
Detailed soils	NCCGIA
Roads	TIGER files
Hydrology	TIGER files
Housing and population for census blocks	IRSS (2)
Land use/land cover	own digitizing
Topology (50-foot contours)	own digitizing
Location of major dairies	own digitizing
Zoning	own digitizing
Wetlands	digitized from UDSI NWI (3)
Municipal jurisdictions	own digitizing

(1) NC Center for Geographic Information and Analysis
(2) Inst. for Research in Social Sciences, UNC-Chapel Hill
(3) US Dept. of the Interior, National Wetlands Inventory

The Soil Conservation Service is providing assistance in the development of combinatorial rules for reducing the large number of detailed soils categories to a smaller number of development-related and environmentally sensitive categories. Particular attention will be given to attributes that are pertinent to construction, on-site waste disposal, and agricultural activities.

Some of the data sets used in this analysis, especially those for soils data, are large relative to the capacity of personal computers. However, a 100-MB external hard disk drive that requires no internal connections proved to be a ready solution to the storage problem.

Conclusion

Experiences with the use of a desktop GIS system for the array of problems discussed in this article lead to several conclusions. First, these sytems provide a powerful analytical aid. Some software products do not require a great amount of training, and in several cases, analysis of complex problems can be done at very modest cost. In particular, the analysis of watershed policy of the kind reported in this paper would not have been feasible without the use of GIS. Second, the cost of analysis can be greatly reduced by exploiting readily available data sets. The TIGER files and census data are especially useful, and they are easily imported into GIS, either through commercially available software or relatively simple self-written programs. A third conclusion is that personal computers with 2 to 4 MB of RAM and hard drives of 40 to 80 MB have an impressive capability for the analysis of problems of considerable size.

The most substantial difficulty encountered in the problems discussed in this paper was matching addresses in utility customer files with those in the TIGER files. That problem may not be present in many communities where land records have been completed and cross-referenced to street files. WRRI-UNC is pursuing the use of a global positioning system for meter-readers to locate customers in the field. That technology is capable of assigning longitude and latitude to water meters within acceptable tolerances.