Archaeology Predictive Modeling

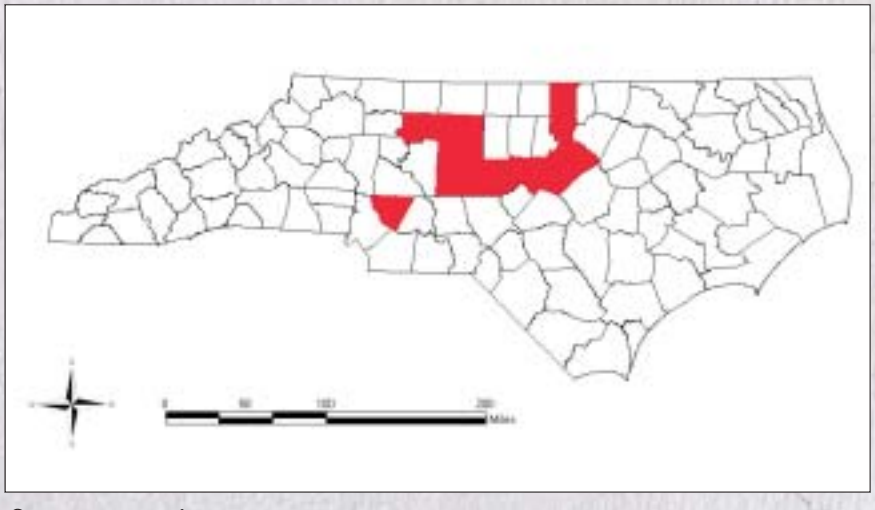
Using GIS to predict location of archaeological sites that impact a transportation improvement program.

By Scott Seibel

Archaeological issues have become a critical element of many transportation projects because of state and federal regulations and an increasing awareness by transportation planners of cultural resources. Recently, transportation planners have begun to recognize the potential of using GIS technology to predict the location of archaeological sites that might be impacted by a transportation improvement program and to minimize adverse effects on these important cultural resources. A computerized mapping and analysis system that has broad use in both the government and private sectors, GIS also provides a powerful, integrative environment for the mapping, analysis, and modeling of cultural resources over a given landscape and over time.

In October 2002, Environmental Services, Inc. (ESI, Raleigh, NC) and GAI Consultants, Inc. (GAI, www.gaiconsultants.com) initiated the development and implementation of a statewide GIS-based Archaeological Predictive Model on behalf of the North Carolina Department of Transportation (NCDOT). This work was conducted at the request of NCDOT, and funded by the Federal Highway Administration (FHWA), with the intention of using the model in the planning of multi-lane highways in new locations throughout the state. This project is only the second statewide effort of its kind.

When fully complete, the model will integrate available environmental and archaeological site data to rank proposed highway corridors and alternatives as reflecting high, medium, or low probability for containing archaeological sites of all periods. Data will be accessed using a decision support system (DSS) based on the ArcIMS (ESRI, www.esri.com) Internet Mapping System. To date, the first two tasks of the project, which included data collection, prehistoric archaeological site modeling for seven counties in the North Carolina Piedmont, and the design of a DSS, are nearly complete.



Seven-county project area.

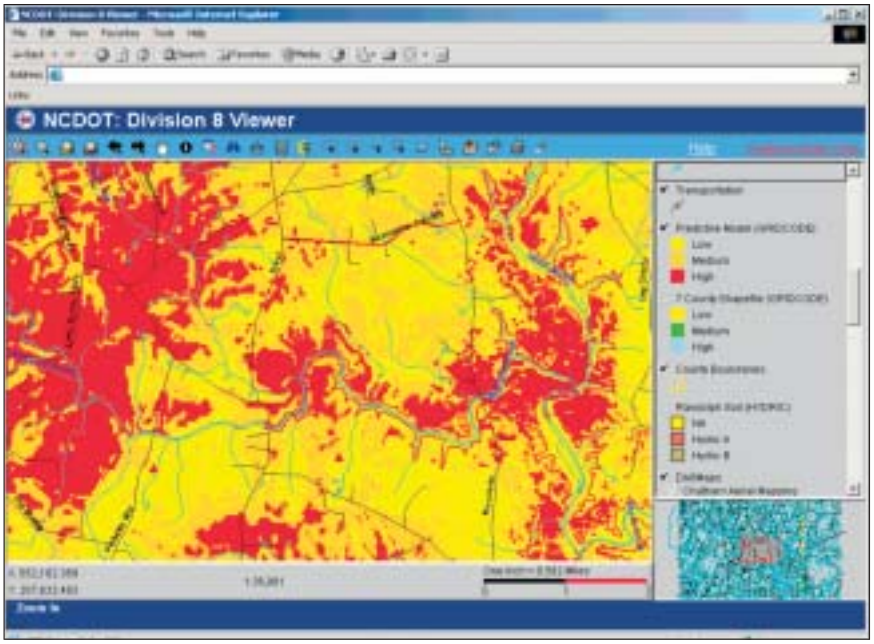
Expediting Selection of Alternatives

Preparation of GIS-based archaeological predictive models will benefit NCDOT by expediting the selection of preferred highway alternatives, thereby decreasing costs of archaeological investigations and reducing project schedules, and should serve as a cost-effective management tool when planning *National Environmental Policy Act* (NEPA)/Section 106 (*National Historic Preservation Act*) projects. This work is intended to provide these capabilities to NCDOT and to modernize the organization of archaeology data at the Office of State Archaeology (OSA).

The merged NEPA and United States Army Corps of Engineers (COE) Section 404 permit process allows for preliminary design and environmental data to be gathered and analyzed for selection of the best alternative for construction of a given project, designated as an Environmental Assessment (EA) or Environmental Impact Statement (EIS) level undertaking. This increase of environmental consideration at the front end of the NEPA process is designed to foster better decision-making regarding selection of a given EA or EIS build alternative.

Preservation and Reduced Costs

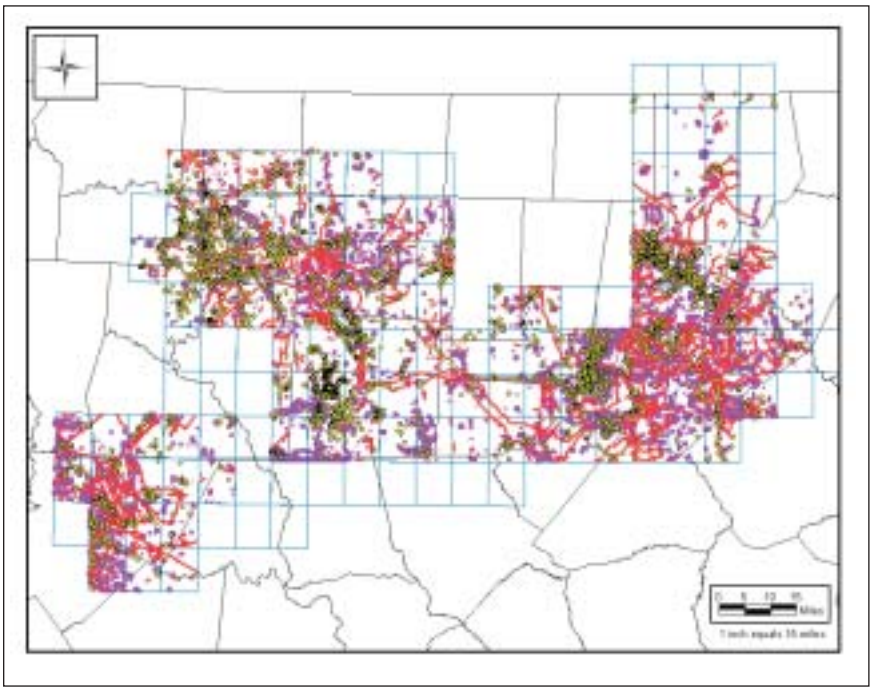
The use of GIS technology for predicting and quantifying potential impacts to archaeological sites is a new tool that can significantly streamline the identification of archaeological resources by NCDOT early in the



Screen capture from the ArcIMS DSS.

NEPA process. This approach will provide transportation planners with quantitative data early in project planning as multiple corridors are being assessed for environmental constraints.

Just as important will be the dynamic nature of the information produced. The GIS approach will allow planners to adapt to changes that occur throughout the life of a given project, including modifications to existing corridor alternatives or the addition of new alternatives. Using GIS, a clear understanding of the archaeological potential of a new or revised alternative can be generated quickly without the need to conduct additional fieldwork or create/revise addenda to an existing report. Avoiding areas of high archaeological potential is expected to preserve many important sites, while significantly reducing costs for NCDOT.



Digitized archaeological data from the Office of State Archaeology.

The GIS approach already has proven itself of value on a statewide level. The Minnesota DOT was the first such agency in the nation to use a GIS-based archaeological predictive model, known as Mn/Model, to better predict the potential for encountering archaeological sites. This model predicts that about 85.5 percent of pre-1837 cultural resources are located in 23 percent of the land in Minnesota. Total cost savings over the four years since the model began to be used in planning new projects have been documented at $3 million per year. The cost of the project was recouped in two years.

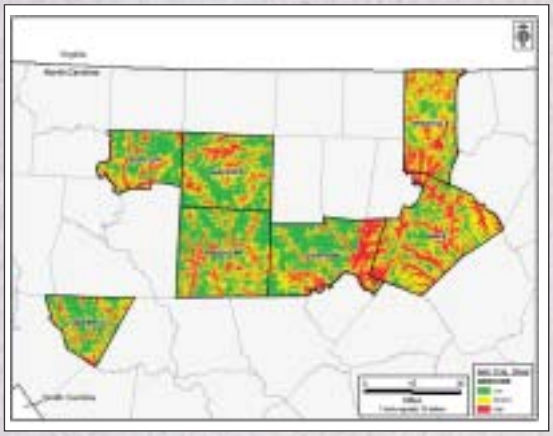
Enhanced Interagency Coordination

Another key benefit of this approach involves coordination with state and federal agencies responsible for compliance with NEPA and Section 106. To make the GIS approach work, the massive amount of archaeological site data at OSA must be available for review and analysis in digital format. These data are currently maintained primarily on paper and microfiche. The NCDOT project is also helping create and maintain a modern digital site database for OSA for its future data management as well as to use in probability model development.

Archaeological site probability information also can be made available to planning organizations throughout the state on an as-needed basis, including certified local governments, cities, county agencies, and regional planning organizations.

Data Collection and Model Development

Task 1 of the NCDOT project involved the collection of archaeological and environmental data covering seven counties in the Piedmont region of North Carolina and the integration of the data into a project database. Existing digitized environmental information was collected, including soil data, geological base mapping, USGS 1:24,000 quadrangles, geomorphological data, and aerial photography, among others. These data were integrated with digitized current archaeological site data from the OSA and historical map data



Final seven-county archaeological predictive model.

from the North Carolina State Archives. The data collected during Task 1 represented a 20 percent sample of the Piedmont physiographic province and 7.6 percent of the total area of North Carolina. This area also contained 16 percent of the recorded archaeological sites in the state.

Task 2 of this project, which is currently nearing completion, includes the development of a prehistoric archaeological predictive model covering the seven counties of the project area. The modeling followed an inductive approach using logistic regression and a total of 4,840 archaeological sites to identify and rank a wide range of environmental variables—including topographic variation, aspect, solar radiation, distance to confluences, and distance to water—for their predictive power. Patterns of co-occurrence were statistically determined, and areas with similar patterns of occurrence were then "predicted" to be of higher likelihood to contain similar archaeological remains.

Traditionally, GIS applications in archaeological research have focused on modeling prehistoric site locations based on the distribution of a suite of environmental variables similar to those mentioned above. Use of GIS in historical research has focused more on the display of cartographic data, reference to site function, and locational analysis than on the formulation of spatial models of historic archaeological site location.

As the first attempt to develop both historic and prehistoric models for such a large area, this project should lead to a more comprehensive understanding of archaeological potential over a given project area.

Analyzing Scales of Models

As part of the modeling effort, the project team investigated appropriate modeling scale. One model for a large area might be easiest to prepare, but it might be too generalized. Individual models based on county or quad map boundaries might be more locally appropriate, but there would be "edge effects" on the borders. Three scales of models were created using traditional techniques: the entire study area, individual counties, and individual quads.

A fourth model was created using a new "roving window" technique, which was used to create a model for individual quads based on the environmental and archaeological data for that quad and the eight surrounding quads to maximize the local distribution of sites while reducing the edge effect problem. It is also useful in areas with few recorded sites.

Model Validation

The predictive power of the models was tested against three control data sets and a field test. The three control sets were a ten percent withheld sample of the total archaeological sites (n=484), an independent University of North Carolina lithic diagnostic database (2,242 data points), and 1,201 sites on the edges of quads that were not located in the seven counties. A detailed field survey was conducted for the US 64 Asheboro Bypass in Randolph County, which included 3,183 shovel tests excavated at 30-meter intervals, which matches the scale of the model. A total of 285 positive shovel tests, representing 84 prehistoric and historic sites, were mapped using a Trimble ProXR (www.trimble.com) global positioning system (GPS).

The models were tested against these field results and the three control data sets. Results indicate that there was a general improvement in modeling power as the scale of analysis was decreased, that is, from the overall seven-county model to the county, roving window, and quad-based models. In general, the quad based models performed the best. However, any increase in predictive power over the seven county model was offset by the fact that the individual models were created with different sets of environmental variables and thus had very different patterns and characters. Overall, the seven county model had significantly robust predictive power and had the benefit of a standardized approach over the whole seven county project area.

A Decision-Support System

Finally, the project team completed development of a DSS based on the ESRI ArcIMS platform. As of May 2006, the project was preparing to deliver the system to coordinate delivery of the system with NCDOT and its GIS department. When placed on the secure NCDOT server, the web-based DSS will allow approved NCDOT users to view digitized archaeological sites and historic maps, as well as topographic maps, aerial photos, and the predictive model as they relate to proposed highway corridors.

The DSS will include tools to quantify potential impacts to aid in the ranking of corridors for the department's NEPA and Section 106 planning purposes. Using the DSS will allow NCDOT to use the predictive model to aid in the selection of highway corridors with the goal of minimizing adverse effects to archaeological sites.

Archaeological predictive modeling has shown itself to be a useful tool for research and planning purposes at a variety of scales. GIS models can provide practical benefits, including more efficient planning, and incorporation of cultural resources early in the local, NEPA, and Section 106 planning process. The ultimate goal is to reduce disturbance of cultural resources and increase our knowledge of the past. GE

Mr. Seibel, a Registered Professional Archaeologist, is Assistant Vice President and Archaeology Division Manager of Environmental Services, Inc., in its Raleigh, NC, office.