FEATURE

GIS and Planning

by Thomas L. Millette, Ph.D.

It has been some fifteen years since I last wrote about Geographic Information Systems (GIS) for the *Planning Commissioners Journal*. Not surprisingly, there have been some substantial changes in the technology and uses since then. My goal here is to update you on some of the more important changes that have taken place in GIS and how they have benefited local and regional planning activities. I will also share with you some creative applications of GIS for planning that I hope will be of interest.

My original *PCJ* article was organized around the *hardware*, *software*, and *database* components of a GIS system. I continue to think that this a useful way to conceptualize GIS, but today I would add a fourth component: *infrastructure*.

1. Hardware

At the risk of dating myself, over my career I have seen cartography evolve into computer mapping and subsequently into GIS. The platforms for these activities have evolved from the light-table, to the mainframe, to the minicomputer, to the microcomputer.

At this very moment, I am collaborating with some folks in developing a field-based GIS system that connects field crews walking along a river with palm-top mapping devices, with a light aircraft flying digital imagery above, with a file-server floating in a boat, all in real-time, and all connected by a Wi-Fi network.

To say that hardware technology has evolved rapidly would be a bit of an understatement. However, if I were to identify the most important hardware advances over the last fifteen years in terms of local planning activities, I think they would be: the commodification of microcomputers;[1] the innovation of microdevices; the continued enhancement and accessibility of the Global Positioning System (GPS); and the maturation of the internet.

The truly global commodification of microcomputers by firms such as Dell, HP, and Lenovo has resulted in an abundance of extremely powerful machines that are highly reliable and affordable. This combination of power, reliability, and low cost, creates the opportunity for the smallest of planning enterprises to acquire and manage a suitable GIS host.

> THE BOTTOM LINE IS THAT GIS HAS GONE FROM A SOMEWHAT EXOTIC TECHNOLOGY TO AN INDISPENSABLE TOOL IN THE CRAFT OF PLANNING.

The innovation of microdevices such as palm-top computers and hand-held GPS receivers has allowed small planning operations to leverage staff and volunteer time to develop GIS data on short lead-times and modest budgets, without needing to rely on expensive consultants. Private industry has given us a plethora of innovations that have made GPS receivers smaller, smarter, GIS-friendly, and remarkably inexpensive.

The maturation of the internet has resulted in a revolutionary high-speed, low-cost infrastructure and conveyance system to view, exchange, and market GIS data and services. For example, you can search, locate, and download to your personal computer the entire GIS road data layer for the State of Massachusetts in approximately three minutes if you have a broadband connection. If that isn't amazing enough, it's all free: the use of the search engine to find the data, access to the data archive at MassGIS, and downloading the data to your personal computer for use as you see fit.

2. Software

GIS software in support of local planning activities has continued to evolve, although not at the accelerated pace of hardware innovation. The most significant changes in GIS software over the last fifteen years include the addition of graphic user interfaces (GUI) to programs and the development of a relatively rich after-market specialty software industry that produces add-ons to mainstream GIS software. GUIs are a significant improvement to software because they allow a broader community of users, particularly the less technical among us.

After-market software innovators have developed a wide spectrum of specialized tools that work as add-on functions within mainstream GIS engines such as ESRI's *ArcGIS* and Pitney Bowes' *MapInfo*. These add-on functions are quite varied and can include basic housekeeping functions like handling large images such as aerial photography and satellite imagery (e.g., *GeoExpress* developed by Lizard Tech, Inc.) or more specialized tasks such as watershed analysis (e.g., *BASINS* by the U.S. EPA), or parcel mapping (e.g., *AV-Parcel* by Cedra Corp).

3. Database

In my mind, one of the most surprising changes in GIS for planning over the last fifteen years has been in the area of data development. It would not be much of an exaggeration to say that initially planners did more GIS data development than GIS analysis. In those early days planning staff would be chained to digitizing tables converting zoning maps, parcel maps, road maps, and anything

1 The "commodification" of microcomputers, that is, their increased standardization as a result of competition in the marketplace, has led to substantial cost reductions, making applications, like GIS, more broadly available.

else they could find into GIS data layers.

These days, you would be hard pressed to find a digitizing table in a planning office or anyone who knew how to operate it. Today there is a rich GIS data infrastructure created by federal, state, and private sector agencies that is generally high quality, mostly free, and delivered by the web.

This dramatic change in the GIS data milieu is due in large part to a considered effort on the part of spatial data users at multiple levels of government (federal, state, county, municipal) to coordinate and cost-share spatial data development. For example, many states have statewide digital orthophotography (aerial photos registered to map coordinate systems) programs that are funded by a collaboration of state and federal agencies. The same is true for national wetland, soils, and land use data, all of which is critical to various aspects of planning.

4. Infrastructure

The single largest change in GIS over the last fifteen years is that there is now a robust infrastructure to support the technology and its use. It includes a large collection of hardware and software developers, and countless governmental and corporate data developers. Federal, state, county, and municipal agencies host websites to make spatial data available to planners at no cost.

GIS has also benefitted from an elaborate consortium of research, education, and training organizations. There is now a generation of professionally trained planners that has had GIS as a prominent part of their curriculum. Virtually every municipal, county, and state planning agency has staff with some GIS expertise. More impressively, many small town planning boards, zoning boards, and conservation commissions that are primarily composed of citizen volunteers are well-versed in the uses of GIS and are often the most vociferous proponents of its adoption. *Citizen Volunteers Put GIS Into Action, p. 16.*

The bottom line is that GIS has gone from a somewhat exotic technology to an indispensable tool in the craft of planning.

GIS Applications for Planning

Since planners were among the earliest adopters of GIS, there is no shortage of interesting applications to showcase. However, since I have a limited amount of space, I thought I'd share with you three useful (and, I hope, interesting) GIS applications.

1. GIS and Build-Out Analysis

A build-out analysis can be a highly useful exercise for a town that would like to monitor development policies (such as zoning) and their impact on infrastructure, the natural environment, community character, and the local economy. Typical build-out analyses help communities deal with questions such as:

- How much land can be developed under existing land use regulations, and where will this growth take place?
- What is the number of residential lots available to be developed, and what will the town's population be at full build-out?
- Do the densities of development called for in the town plan seem appropriate to their location, existing infrastructure, and the natural environment?
- Are there areas of the town zoned for development that the community may want to consider keeping undeveloped?

Pine Plains, New York (population 2,569 as of the 2000 Census) is located in northern Dutchess County, about 90 miles north of New York City and 60 miles south of Albany. Given the town's location and natural beauty, it has been facing strong growth pressures. In 2004 the town adopted a comprehensive plan that includes a focus on growth and development and preservation of the natural environment.

As the plan notes, the results of a town-wide questionnaire indicated that: "The town's lack of zoning was one of the most negative features in Pine Plains. Most development has occurred outside of the town center, and unplanned or uncontrolled development is contributing to the loss of agricultural land and community character. Specifically, uncontrolled development and lack of

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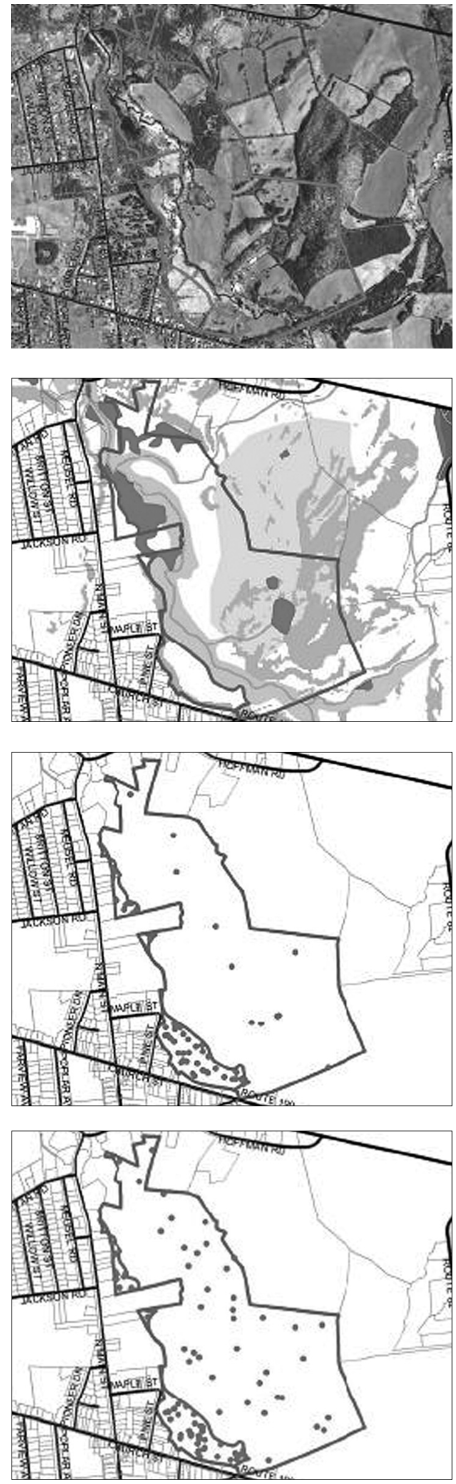

GIS has helped members of the newly formed Pine Plains zoning commission evaluate various zoning alternatives – both at the town-wide level and as applied to several large parcels, as shown in the sequence above. Topmost: aerial photo of the "Sunnyside" parcel; next: view of areas on the parcel having environmental constraints; next: potential housing build-out of the parcel with 10-acre base zoning; next: potential build-out with 3-acre base zoning.

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proper land use control was perceived as the most significant threat to the rural character and quality of life in Pine Plains."

As a result, the comprehensive plan included as a goal that "new commercial and residential growth will be consistent with the cultural and environmental conditions of the area as well as with our rural character." Among the strategies for accomplishing this, "implementing a land use program that sets densities based on the land's ability to support development." The plan also sets out a series of environmental standards, including areas where new development should be avoided.

Following adoption of the comprehensive plan, the town's governing board appointed a zoning commission to develop land use regulations to implement the plan's recommendations. But the commission quickly realized the difficulty of determining the possible impacts of different zoning scenarios. One important concern, for example, was how various densities would affect maintaining the town's agricultural base.

As Nan Stolzenburg, a consultant who had been working with the town on the comprehensive plan and its implementation, describes, "doing nothing was totally unacceptable, but the zoning commissioners were having trouble figuring out the likely results of possible density alternatives." As a result, the decision was made to use a GIS-based approach to conduct a build-out analysis for the town.

NAN STOLZENBURG

Pine Plains, New York, used GIS to help develop zoning districts and densities that would best implement the town plan, which sought to provide for new development, while maintaining the character of both countryside and existing hamlets.

Editor's Note:

Citizen Volunteers Put GIS Into Action

In response to our circulating Thomas Millette's first draft for review, I received a reply from Barbara Sweet that I wanted to share with *Planning Commissioners Journal* readers.[1]

Sweet, who lives in the Town of Hyde Park, New York (birthplace of President Franklin D. Roosevelt), has become skilled in using GIS. As she describes it, "retired, I took a college course (at Marist College in nearby Poughkeepsie) to get my feet wet." Sweet then became a "regular" at monthly meetings of an informal group of citizens from area towns who are interested in how GIS can help their towns' planning and zoning boards and conservation advisory councils.

The monthly meetings are one of several GIS-related services offered by Cornell Cooperative Extension Dutchess County (CCEDC). I spoke with Neil Curri, Senior GIS Resource Educator with CCEDC. Curri explained how, with financial support from the County, the "GIS lab" provides both professional planners and citizen volunteers with resource data and training opportunities, as well as access to the County's GIS and property searching tools.

Curri is particularly pleased with the GIS special interest group. Meetings cover a wide range of topics. Most recently, participants learned how GIS, drawing on Google Earth, can help map out the spread of invasive plants – a growing concern in this part of New York.

Why do citizen volunteers care about GIS? For Sweet, it's a way of helping her town more effectively protect natural resources to ensure things like safe and clean drinking water (by mapping out well and septic system locations, and determining how much acreage is needed to support them). More recently, she has been learning about "hill shade" analysis – using GIS to map data on the length of time and intensity of the sun in given locations. This could help identify those parcels on which dwelling units may be able to effectively use solar power.

Jerry Ottaway, a resident of the nearby town of Pleasant Valley, stressed to me the benefits that volunteer efforts can provide in bringing GIS to smaller communities with limited staff. Teddi Southworth, another member of the Pleasant Valley Conservation Council, regularly generates maps for use by the planning board – drawing on the resources provided by the CCEDC GIS lab.

Other area residents working with the GIS lab have used GIS to develop a proposed town trail map; determine buffer zones for hydric soils and wetlands for use in a proposed wetlands ordinance; and map out local gravel deposits – to cite just a few examples.

Recently, CCEDC created a more formal GIS volunteer program. Drawing enrollees from members of the GIS special interest group, participants in the program will receive training in a number of GIS tools and techniques that can be applied to local needs. The volunteers will then put this training to use through a service commitment on behalf of the CCEDC GIS lab, assisting Curri to provide GIS training and services in the county.

With training and mutual support, local residents in Dutchess County, New York, have used GIS to help their towns better analyze a range of land use and environmental issues.

1 Some 300 citizen and professional planners help us out by reviewing and providing feedback on first drafts of articles scheduled for publication in the *Planning Commissioners Journal.* As a *PCJ* reader, you are welcome to participate. Simply go to: <www.plannersweb.com>, then look for "Review Draft *PCJ* Articles" in the right-hand column (you'll need to scroll down the page) and use the link to our sign-up form.

The process began by taking a parcel map of the town and dividing it into the proposed zoning districts as recommended in the town plan.

The second step was to use the GIS to identify all parcels that would not allow additional development (road, utility, and rights-of-way corridors; fully built parcels; and parcels with conservation easements).

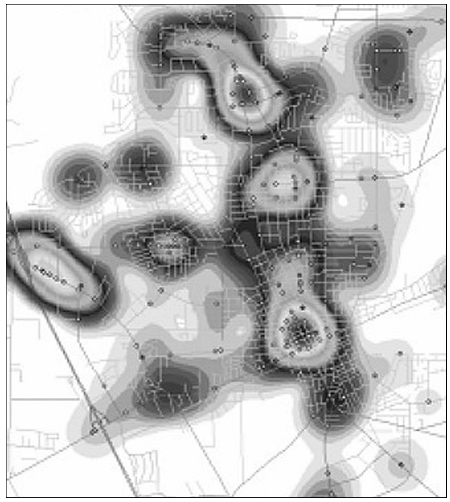
The third step was to identify environmentally-constrained areas as recommended in the comprehensive plan. These areas included: 20 foot buffers of streams; wetlands; slopes greater than 15 percent; shallow soils; and the 100 year flood hazard zone.

The final step was to calculate potential new residential units for each parcel using a variety of scenarios that manipulated differing zoning densities and weighting for the environmental constraints.

The build-out provided some useful and interesting metrics. For example, town-wide there are a total of 1,450 parcels that are smaller than 20 acres, of which 889 are buildable – which would potentially yield 664 new residences (using a five acre minimum lot size and respecting all environmental criteria except soil depth). There are also a total of 169 parcels larger than 20 acres, of which 137 are buildable, potentially yielding 1,445 potential new residences using the same criteria.

The build-out analysis also "zoomed in" on several large individual parcels. See map sequence on page 15. As Stolzenburg explains, "the zoning commission was very pragmatic, and wanted to know what the zoning alternatives would mean to some of the major landowners in town." The use of GIS enabled the zoning commission to draft land use regulations that would not only conform to the town plan's recommendations, but also be acceptable to residents as applied on the ground.[2]

As Pine Plains found, it is the opportunity to experiment with varying development and environmental criteria and see their impacts on a town's land-base, settlement patterns, and infrastructure needs that makes a GIS driven build-out analysis extremely valuable.



SOUTH GEORGIA REGIONAL DEVELOPMENT CENTER

GIS was used to map out accident "hot spots" in Valdosta, Georgia.

2. GIS for Public Safety

The South Georgia Regional Development Center (SGRDC) has used GIS to creatively analyze traffic accident data to better understand the geographic pattern, context, and attributes of crashes in Lowndes County, Georgia.

The study made use of data collected at the scene by local law enforcement personnel for each traffic accident. This information included the street address, time, date, road conditions, and probable cause (speeding, failure to grant right of way, failure to heed stop sign, reckless driving, etc.) for each incident, which was added to the agency's GIS.

Once in the GIS, the traffic accident data was analyzed together with road, parcel, infrastructure, land use, and census data. This included looking at accidents and traffic violations in locational context (specific roads, at particular intersections, associated with specific types of residential or commercial activity, signage, and so on).

The GIS study turned up a number of interesting patterns. For example, the majority of crashes did not occur at mid-block, but rather at collectors and intersecting local streets. Looking more closely at these high accident locations, most did not have clearly marked crosswalks, sidewalks, or other pedestrian-friendly features. Additionally, many of the intersections had visual obstructions and poorly designed signage that may have contributed to accidents.

As a result of these analyses, Lowndes County has assessed the design of high accident intersections, modified its sign ordinances, developed a GPS-driven sign inventory, and used the data to better target traffic patrols.

SGRDC also used the accident data to test EMS response for medical emergencies. As background, Lowndes County covers about 504 square miles, with 1,420 miles of roads, and a population of approximately 114,000. A typical year has slightly more than 11,000 calls for emergency service, of which 75 percent are medical emergencies, serviced by four EMS units distributed around the county.

TOM SPINKER

Above, a training exercise to give Valdosta firefighters experience inside a burning structure. The city's fire department and emergency services have benefited from the use of GIS.

The EMS response goal is to reach an accident within six minutes of a call. Using GIS to analyze the road network, locations of accidents, and EMS base locations, it was determined that the best way to reach the six-minute response time, would require three of the four EMS stations to be relocated. Additionally, given population growth trends in the county, it would require a fifth EMS station to be added in the near future.

The GIS modeling for public safety done by SGRDC is a wonderful example of how spatial analysis of community

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2 The recommended zoning regulations, as of publication of this article, were before the town governing body for consideration.

Looking Forward

As I look to future developments in GIS and planning it's safe to assume that computer hardware systems and microdevices will continue to develop at a rapid pace, increasing in functionality and decreasing in cost. There are several new Global Positioning Satellite (GPS) systems due to come on-line in the next few years which should further fuel developments in field mapping tools, microdevices, and spatial database enrichment.

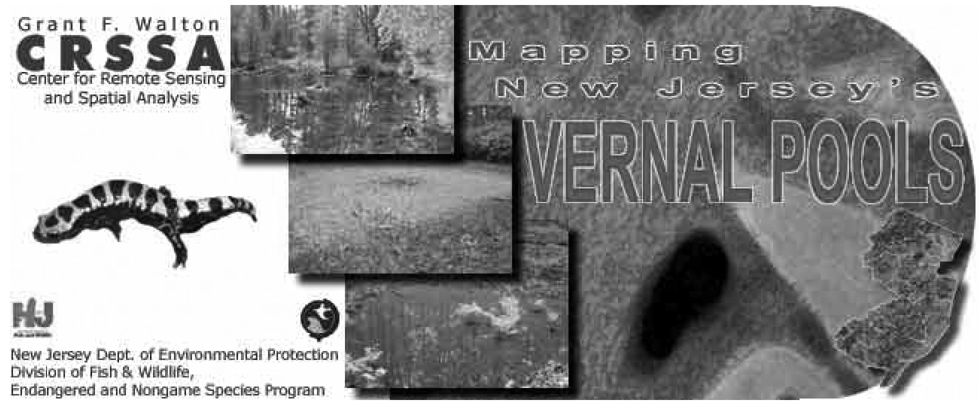
However, I think the most significant advances looming on the horizon will take place in the areas of spatial data/model development and automated planning information system implementation. Planners have used modeling of one sort or another from the discipline's inception. Maps are probably the most common model of the landscape used in planning and generally provide a base upon which quantitative and analytical functionality can be built.

Initial attempts at land use and transportation modeling generally used fairly simplistic representations of landscapes (roads, land cover, settlements, elevation, etc.) and processes (traffic volume, level of service, corridor characteristics, etc.) for GIS modeling. The dramatic increase in the richness and availability of spatial data seen over the last decade will support a significant movement in the next decade in developing more detailed and nuanced representations of the landscape in support of planning analyses.

I believe we will also see a dramatic increase in the development of truly automated planning information systems that will be widely available to the smallest of municipalities.

Most of us are well aware of the information flow often required for site and subdivision review. It goes from the planner's office, to the assessors office, to the conservation commission, building inspector, and so on. Frequently each office maintains and tracks paperwork with different software, or sometimes on paper alone.

Imagine a software environment that consolidates all review procedures of each town office into a single portfolio that is available and editable online from anywhere. Imagine also that the other review, tracking, and permitting activities done at town hall are serviced by the same system. Smile, because it is definitely on the way!



The New Jersey Department of Environmental Protection's Vernal Pools web site provides an interactive viewer that allows users to "drill down" at various levels of magnification. The map on the next page is centered on Bethlehem Township in northern New Jersey. Identified vernal maps are highlighted on the maps; users can choose to display additional layers of information (e.g., wetlands, state or federal protected lands; roads).

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phenomena (such as accidents) can help improve the quality of service, and ultimately life, in our towns and cities. Moreover, the work illustrated here is not complicated or expensive. Most communities already collect this data, and the GIS operations are quite basic.

As a "fringe benefit," the GIS has yielded direct financial savings to area businesses by lowering fire insurance ratings. How's that? As reported in the *Land Use Bulletin* of the National Consortium for Rural Geospatial InnovationS ("Damping High Fire-Insurance Rates: GIS Helps Improve Fire Insurance Rating in Valdosta, Georgia" – March 2001), GIS has enabled Lowndes County and the City of Valdosta to better space fire hydrants and locate "holes" in the hydrant network. "Developing a single, comprehensive database of these hydrant locations has made a significant difference in community ISO [Insurance Services Organization] scores." This, in turn, has resulted in substantial annual savings in insurance premiums.

3. Vernal Pool Mapping and Assessment

The last application I would like to share provides one example of how state agencies are making their expertise and data resources available to towns in support of local environmental planning.

Vernal pools are small depressions that have standing water for at least two months a year, lack an outlet, and are free of fish populations. These temporary wetlands provide specialized habitat for many species of amphibians, several of which breed exclusively in vernal pools, as well as a multitude of insects, reptiles, plants, and other wildlife.

Many communities have begun to plan for biodiversity and are developing programs to map and monitor these sensitive habitats. Since vernal pools are generally small, sometimes numerous, often located in remote areas, and require

site visits to identify specific biota, mapping them can be logistically challenging. Additionally, identifying specific organisms associated with vernal pools requires a modest level of expertise or training.

The New Jersey Division of Fish and Wildlife together with the Grant F. Walton Center for Remote Sensing and Spatial Analysis have developed a very helpful approach to providing community volunteers with the tools and expertise to run their own vernal pool programs – and have packaged it on the web for anyone to use: <www.dbcrssa.rutgers.edu/ims/vernal/graphics.htm>.

The website uses clearly written text and excellent photographs to illustrate the hydrography and biology of vernal pools. It provides forms and aids to support fieldwork. The site also uses a web based GIS to allow town volunteers to gather a host of maps, GIS layers, and aerial photography to help plan and execute their vernal pool mapping program and inventory assessment.

This site has done a great job of distilling important vernal pool ecology and program management tools, matching them with a host of state spatial data. It is a model for how professional natural resource scientists and state government can work together to help town volunteers protect their communities.

Despite the fact that I work with GIS on a daily basis, I am continually amazed at the rapid pace of developments and the richness of the tools and techniques that make it to our desks. I can't wait to see what we will be using and doing a decade from now. ◆

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