GIS Best Practices

GIS for Urban and Regional Planning

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esri

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What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

GIS for Urban and Regional Planning

Planners require solutions that address day-to-day work needs while also fostering the ability to effectively predict and respond to chronic urban problems and future market fluctuation. The success of planners in combating chronic urban problems is largely determined by their ability to utilize effective tools and planning support systems that allow them to make informed decisions based on actionable intelligence. Today, planners utilize GIS around the world in a variety of applications. The following articles illustrate how GIS is being used as a platform to help planners reach their goals of creating livable communities and improving the overall quality of life while protecting the environment and promoting economic development. GIS tools can provide the necessary planning platform for visualization, modeling, analysis, and collaboration.

Effective Growth Management

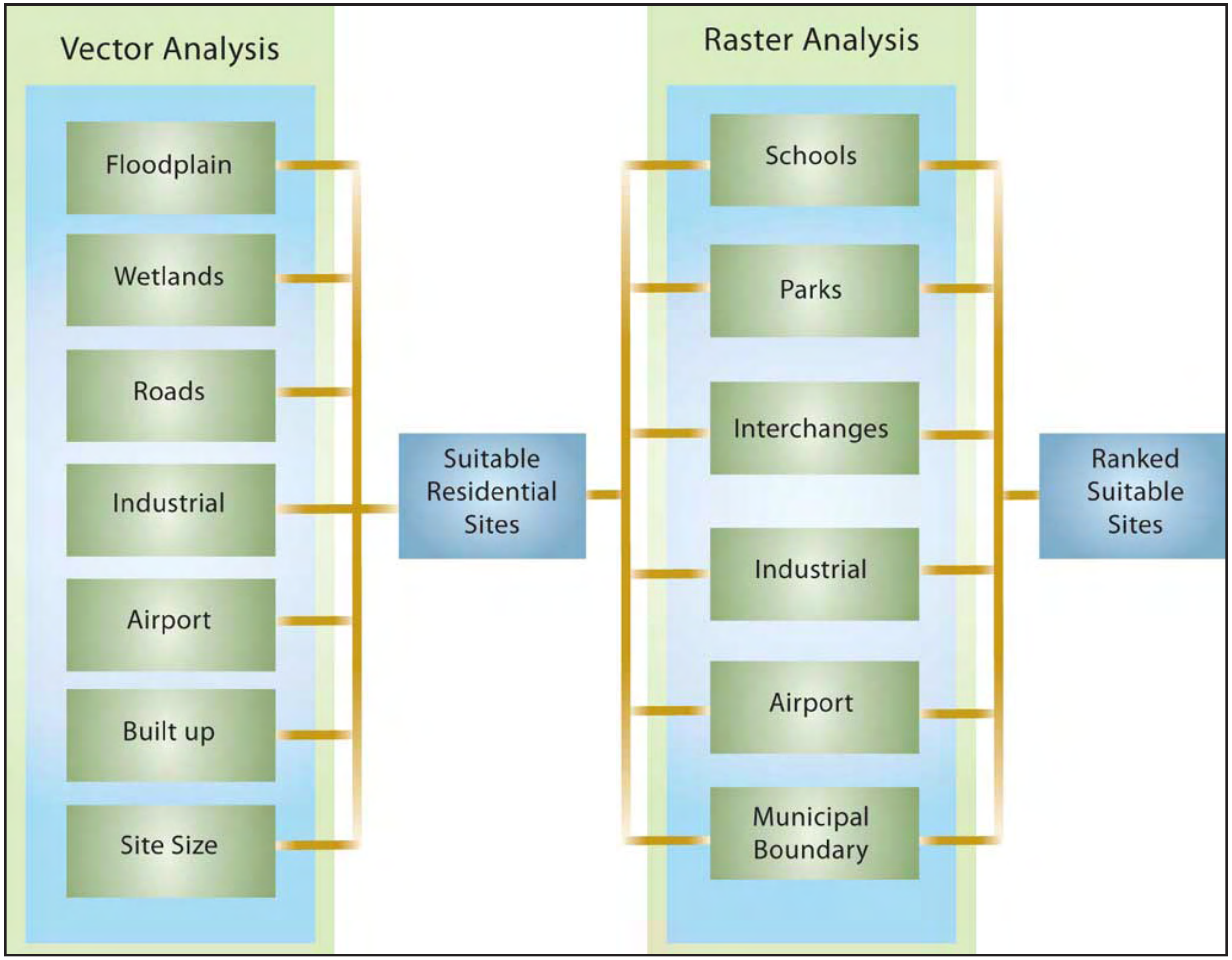
Demonstrating the MCE capabilities of GIS

By Ahmed Baha' Abukhater, the University of Texas at Austin

Summary

The need to make land-use decisions on a national and regional scale in Canada was the impetus for the development of GIS. Roger Tomlinson, the acknowledged father of GIS, led the Agricultural Rehabilitation and Development team that developed what became known as the Canada Geographic Information System. Land use analysis has remained an important GIS application. This article illustrates how criteria reflecting different planning goals can be incorporated into analysis by modifying the parameters of GIS tools in ArcGIS.

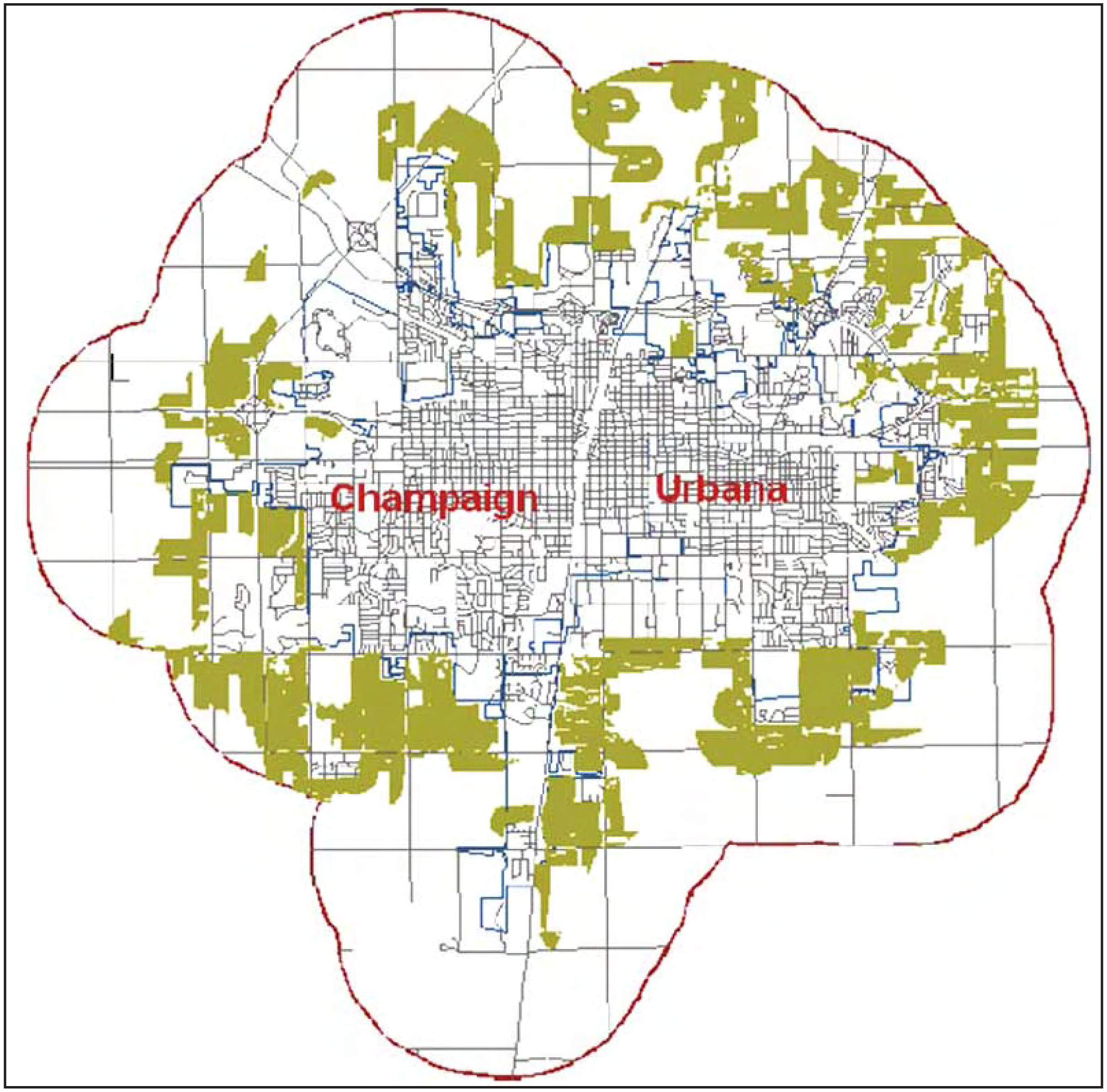
GIS allows for multiple criteria evaluation (MCE). This analysis is mainly characterized by allocating weights to assessment criteria for suggesting and ranking alternatives. GIS spatial planning support tools have an important advantage—changing the valuation criteria to visually illustrate and depict the implications of different spatial decisions and alternatives is convenient. The capabilities needed for decision making readily available in a single system make GIS a great tool for integrating in planning processes. This article describes a study that showed how GIS spatial analytical tools can be used to effectively shape decisions that foster urban growth management.



Overview of the analytical procedure.

Purpose of the Study

The study identified desirable locations for anticipated low-density residential projects in the Champaign–Urbana region, Illinois. The analysis was based on two almost contradictory approaches and compared the resulting maps.



Map resulting from vector-based analysis showing sites initially identified as suitable for low-density residential development.

The sites were analyzed and evaluated according to two scenarios. The first scenario was based on the developer's point of view and took into account the purchasers' preferences. This scenario considered the developer's preferences pertaining to economic and marketing factors. To that end, the developer was interested in maximizing profit and minimizing the cost of the development and paid little or no attention to environmental concerns.

The second scenario was based on the environmentalists' point of view, which is the opposite of the first scenario. In this scenario, sites were ranked and evaluated on potential for engendering environmentally friendly development. In this regard, protecting the agricultural and forest lands and maintaining the integrity of the environment were the most decisive factors in influencing environmentalists' criteria and decisions.

Factor	Requirements
Location in 100-year floodplain and/or wetland areas	The site must avoid floodplain designated areas or areas that have high runoff rates to prevent any environmental hazards.
Soil type	The site must avoid soils with low bearing strength or poor drainage.
Topography	Avoiding sites that have steep terrains reduces the cost of site grading. Constructing on steep slopes means that a tremendous amount of site grading is necessary for adequate drainage and sewage systems.
Site size	The site should be of a minimum size to increase the overall project profitability.

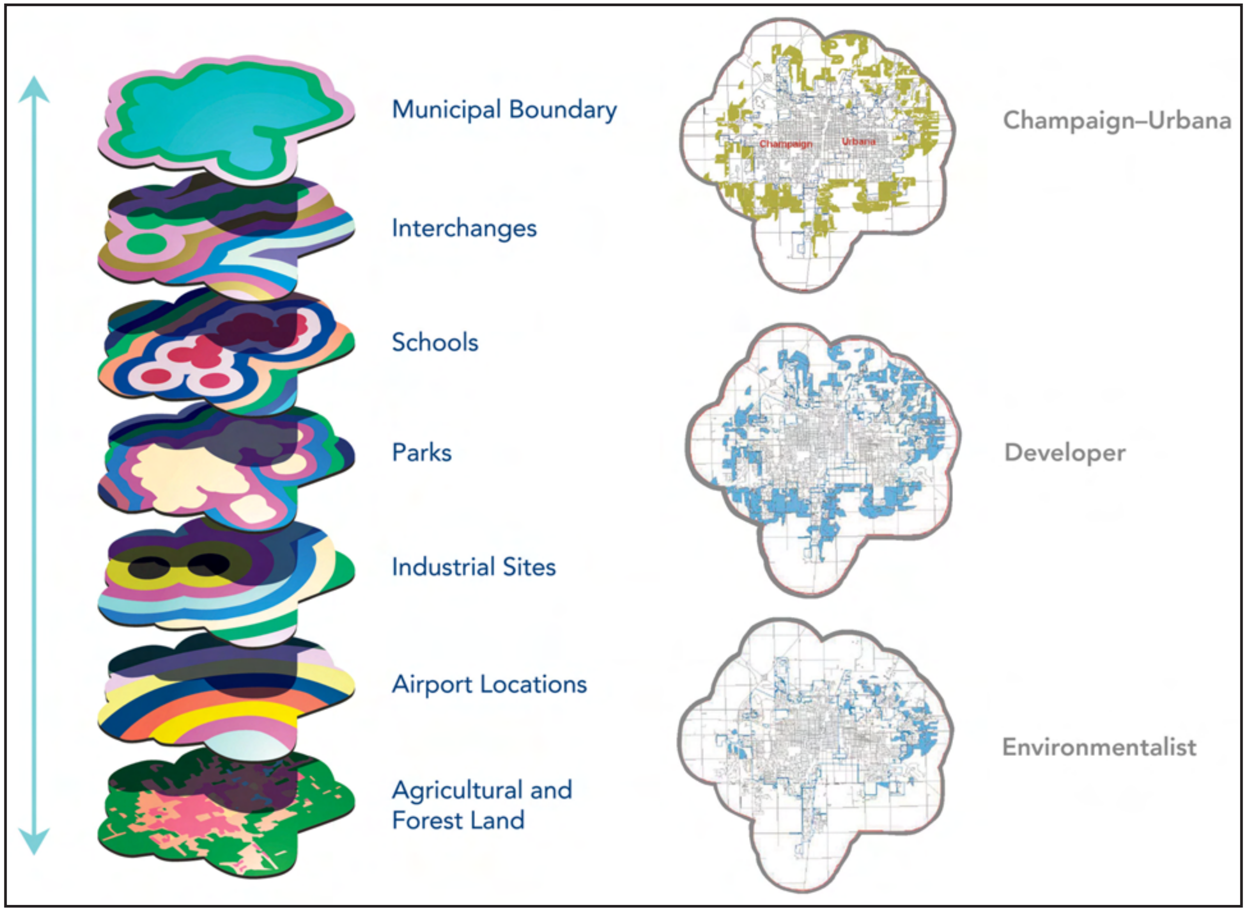
Site-specific selection factors.

Factor	Requirements
Proximity to the existing urbanized areas	The site should be connected to existing residential areas with a high growth potential. This condition ensures that the site is adequately served by the existing facilities and infrastructure. A desirable distance from the nearest built-up areas should not exceed a half mile.
Environmental legislation compliance	To preserve the environmental quality of the area, the site must avoid environmentally sensitive sites and open spaces.
Accessibility	The site must be accessible and well connected by the transportation network to ensure that the commute time required for work, entertainment, or shopping trips does not exceed 30 minutes.
Proximity to industrial and landfill sites	A minimum distance of one mile from landfill and industrial locations and other noxious land uses must be secured to prevent noise and eliminate the immediate threat of chemical emissions harmful to public health.
Airport location	A minimum distance of one mile from the airport, located to the south of the Champaign-Urbana region, was deemed sufficient to avoid adverse impacts of airport noise.

External site selection factors.

Site Selection Criteria

The site selection suitability analysis conducted for the study included weighing the different factors in both scenarios and ranking desirable sites. The outcome of both scenarios was evaluated and analyzed based on features of the site and features of the surrounding area.



The raster layers used in raster analysis.

Analytic Procedures

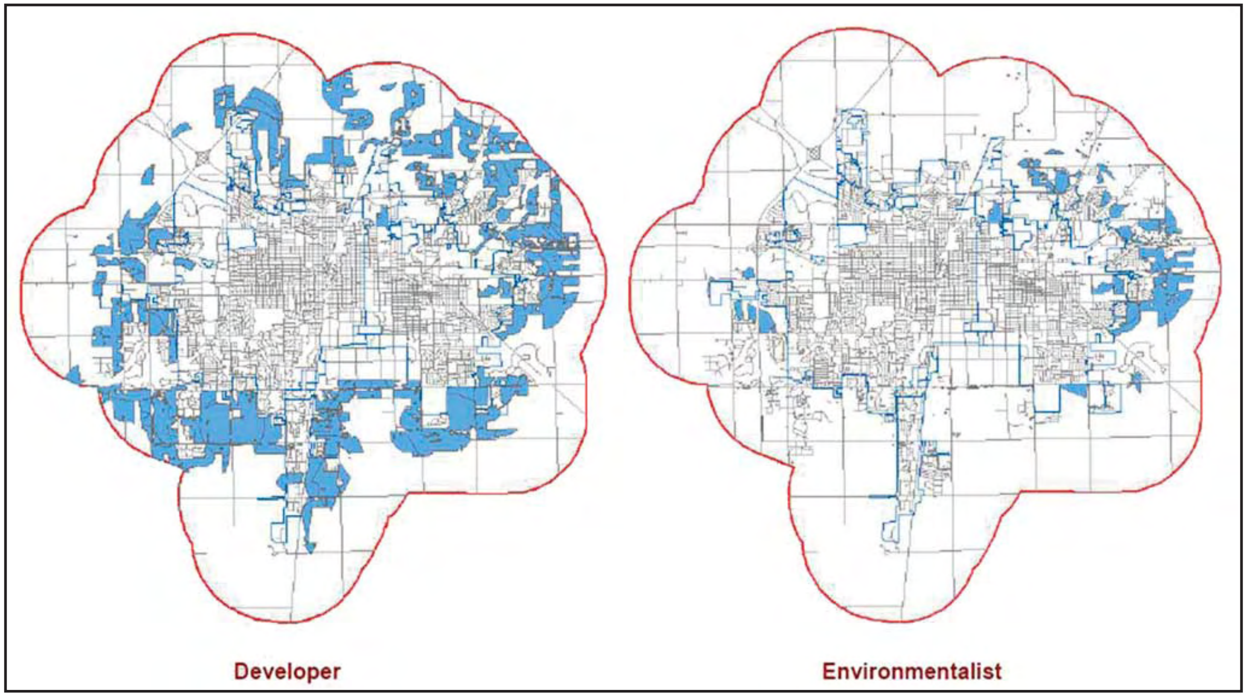
The analytic steps conducted in this study were combined into two major categories: vector analysis and raster analysis.

Vector-Based Analysis

Using vector-based geoprocessing tools, the final layers were juxtaposed on one map that showed sites initially identified as suitable for low-density residential development. At this stage of the analysis, the output did not reflect either the developer's or the environmentalist's concerns.

Raster-Based Analysis

This analysis considered the two scenarios, introduced in the beginning of the study, that represented a developer's viewpoint and an environmentalist's viewpoint. All layers were classified according to a 10-category color scale for consistency purposes.



Maps illustrate ranked sites based on developer and environmentalist preferences.

Conclusion

The findings from this study were mapped and provided a comparison of the results obtained from both scenarios. Suitable areas for the low-density residential development in the developer's scenario cover a significantly larger portion of the region than the environmentalist's conservative scenario. Because developers typically do not pay a great deal of attention to environmental factors, many more areas were proposed for development. Conversely, environmentalists' efforts to preserve the natural resources of the region greatly limited the amount of land perceived as suitable for future development.

This study provided an example of how GIS could be used to support planning tasks and help make better decisions regarding real-world planning issues and develop communities more effectively. It emphasizes the role of GIS in urban growth management practice and land-use planning decision making. The study argued for the full utilization of GIS in ways that maximize its contribution to the planning practice instead of limiting its application to mapmaking and cartography only.

GIS can deliver insights from data by identifying, displaying, analyzing, and deciphering real-world problems. GIS-based technology provides state-of-the-art analytical and management tools to spatially analyze and study patterns and spatial variations and correlations to make more informed decisions.

(Reprinted from the Spring 2008 issue of *ArcUser* magazine)

Singapore Masters Land-Use Planning Using GIS

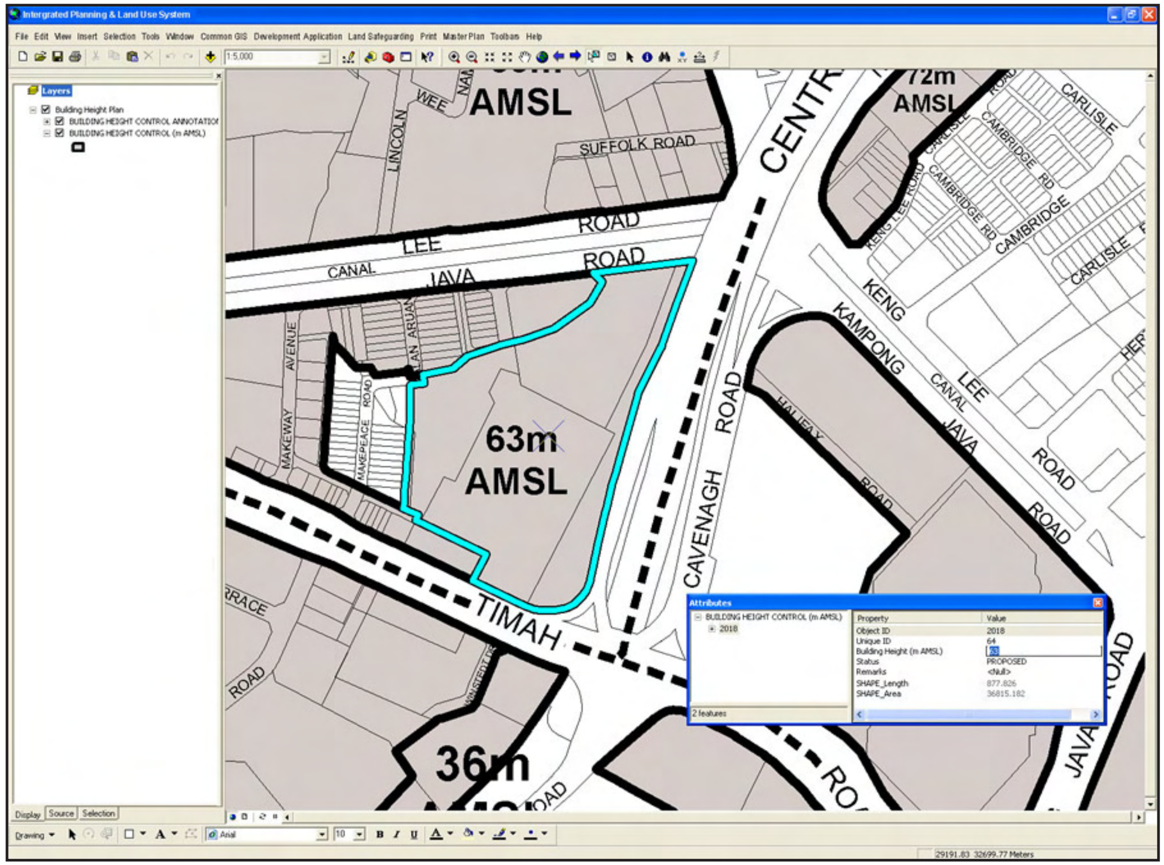
By Matt Freeman, Esri Writer

Singapore faces immense challenges in its land-use planning that stem from the fact that almost five million people live and work within a land area of 710 square kilometers (274 square miles). Given its small size, it's important to carefully plan for the economic growth and future development of the island nation. That's why Urban Redevelopment Authority (URA), Singapore's national land-use planning agency, relies on GIS to find new ways to minimize development constraints.

Singapore's Urban Redevelopment Authority uses GIS for its short- and long-term planning of the Marina Bay cityscape.

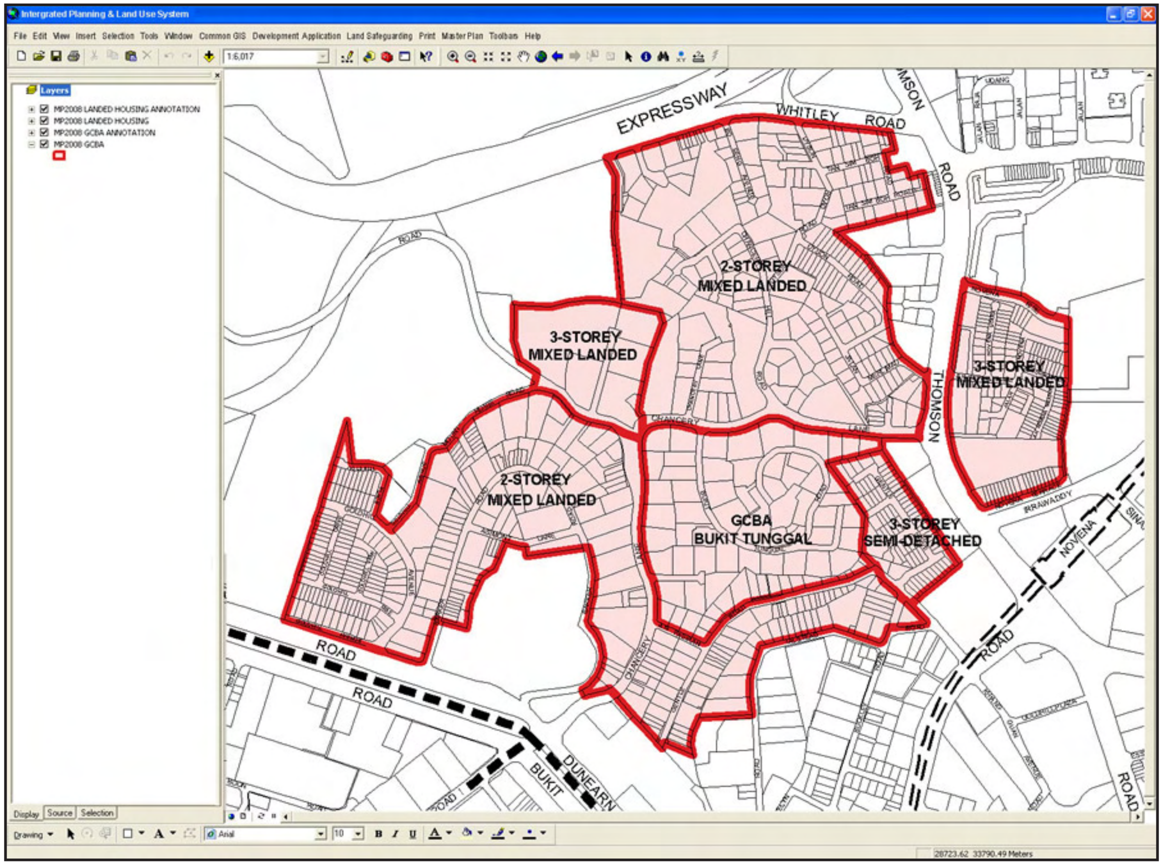
The result of the URA's GIS-based planning can be seen in two key plans, the concept plan and the master plan. both of which provide a comprehensive, forward-looking, integrated framework for sustainable development.

Esri's ArcGIS Server and ArcGIS Desktop software was used to create the plans, while the ArcMap application inside ArcGIS Desktop was customized to fit the workflow needs of the URA. The new workflow system has enhanced productivity through better data integration and more accessibility than had been provided by the CAD system that URA abandoned in 2006. Since switching to a server GIS platform in that same year, more URA employees can access needed data without having to pay for multiple CAD-based desktop licenses. Meanwhile, GIS data is diffused through better access to fundamental workflow tools, such as simple data retrieval services or editing applications.



The master plan came to fruition through careful GIS-based planning and design, such as seen here in the Building Height Control layer.

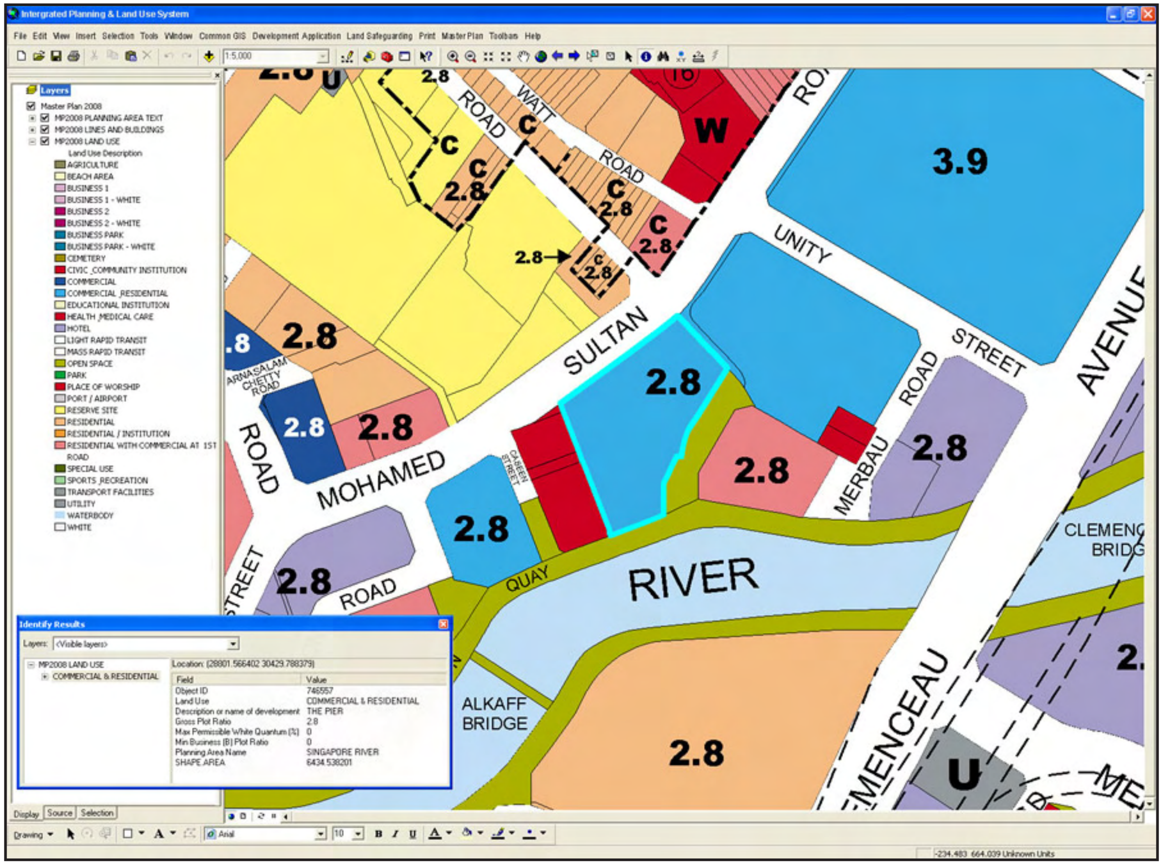
URA takes advantage of an enterprise GIS called LandNet to obtain the geospatial data it needs to create maps for designing the concept and master plans. Hosted by Singapore Land Authority, LandNet is a server GIS-based repository containing more than 100 layers of geospatial data contributed by more than 14 public agencies. Using the shared data from LandNet and the functionality in Esri's ArcGIS software, the URA can create, edit, and publish concept and master plan maps on the Web for employees and the general public to view. URA has 200 professionals working on the master plan alone, all of whom can access data concurrently.



The Landed Housing Areas layer is URA's desktop application for visualizing the height of residential structures.

The master plan is a land-use plan that guides Singapore's development 10 to 15 years into the future. It is reviewed every five years and translates the broad, long-term strategies of the concept plan into detailed plans to guide development. Like the concept plan, the master plan is produced collaboratively among many government agencies in Singapore.

The 2008 master plan is unique in that it took suggestions from Singapore's citizens into consideration before it was finalized. Since the URA could easily publish maps and plans on the Internet, the agency invited the public to give feedback on the rough draft of the master plan. From May through August 2008, more than 40,000 people visited the master plan Web site to view and comment on the GIS maps of the master plan.



In the desktop environment, the master plan contains a land-use layer, which has assigned attributes to each parcel and polygon.

The concept plan is Singapore's strategic land-use and transportation plan to guide development 40 to 50 years into the future. This long-term plan, which will be analyzed and reviewed every 10 years, ensures that there will be sufficient land to meet anticipated population and economic growth and provide a good living environment. It also ensures that future development will balance economic growth with environmental stewardship and social progress.

"There is great value in the ability for citizens to quickly access the maps to determine planned land use surrounding their properties," says Tan Chia-li, URA senior planner. "For average citizens, the master plan is a glimpse into their future. They can envision their community, their nation's progress, and development down to the block level. The master plan lets people peer through a window five years into the future."

For the past 40 years, Singapore has prided itself on sustainable development, which has allowed it to achieve the economic growth that citizens appreciate. By planning ahead and balancing land-use needs, land-scarce Singapore believes it can continue to meet development and economic objectives without sacrificing a good quality of life.

(Reprinted from the December 2009 issue of *ArcWatch* magazine)

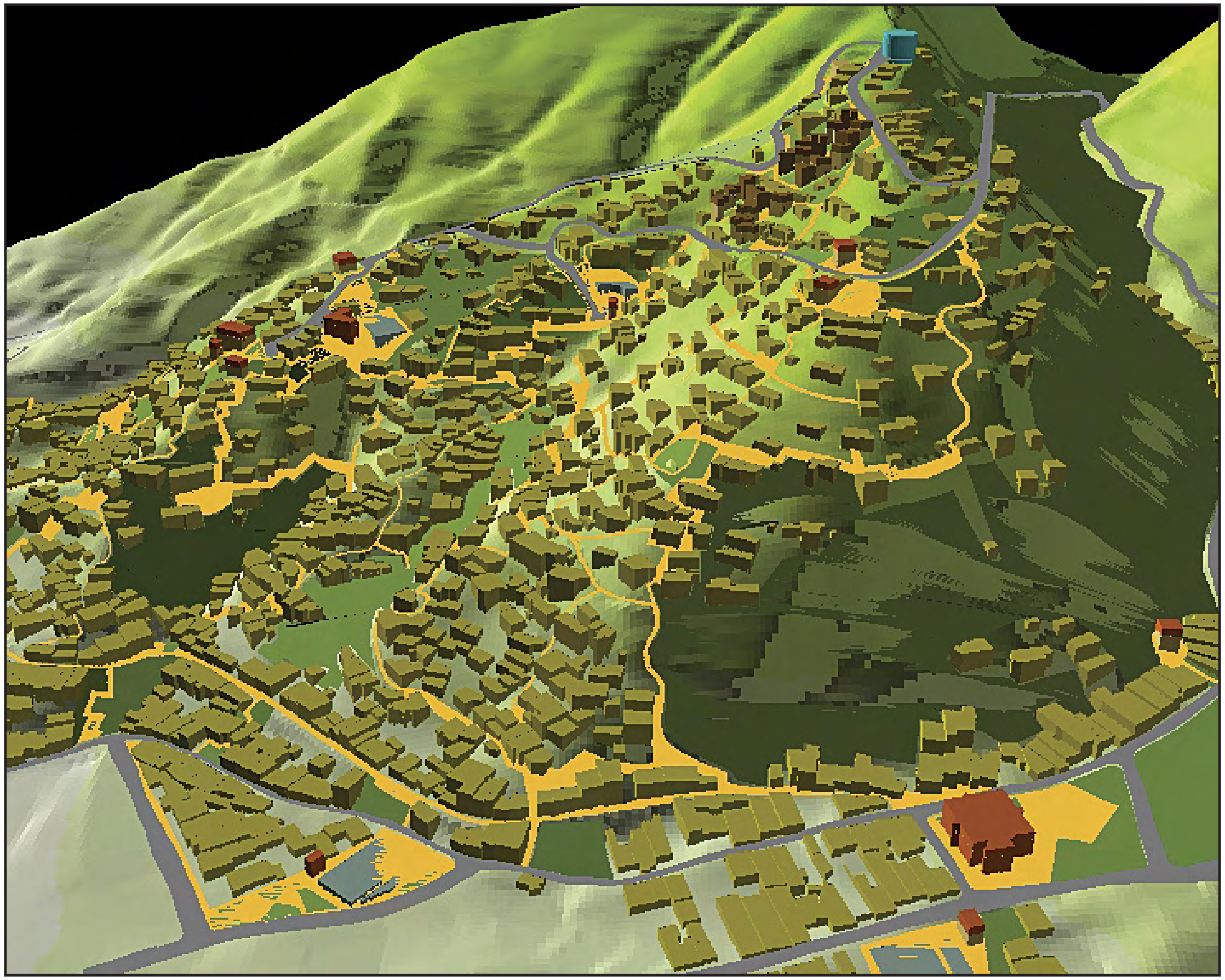
Rosario C. Giusti de Pérez Brings Urban Planning to the Slums of Venezuela

The United Nations Center for Human Settlements reports that more than one billion people in the world live in slums and squatter settlements without adequate shelter and basic services. Worldwide, slums are considered to be residential areas in urban geographic areas that are inhabited by the poor. Because of these characteristics, urban planners can use GIS to manage geographic data about slum areas to show relationships, elevations, landmarks, slope, water sources, and other attributes that affect these urban populations.

Rosario C. Giusti de Pérez, architect and urban designer, exemplifies the importance of combining the human element of concern with the capabilities of technology to turn the tide of despair to one of hope and benefit for the community. Because of her many years of commitment to helping improve the quality of life in the slums (barrios) of Venezuela, Esri recognizes Rosario C. Giusti de Pérez as a GIS hero.

Rosario C. Giusti de Pérez.

Despite the fact that Venezuela is an oil rich nation, approximately 50 percent of its people live in poverty. Those in urban areas have constructed shantytowns with homes made of plywood, corrugated metal, and sheets of plastic. Giusti de Pérez does not see these neighborhoods as targets for the bulldozer but rather as communities whose residents need to be involved in planning and redevelopment.



Barrio Los Claveles, Maiquetia, Venezuela, seen in ArcGIS 3D Analyst.

Many cities do not consider these squatter lands as communities and consider demolition to be a solution to urban blight. But this ruthless approach of displacement creates disorder, increases crime, and adds to the misery of poverty. A slum is more than corrugated tin and plastic; it is human faces, neighborhoods of people with social structures that protect and support their communities. Giusti de Pérez has spent the last 10 years working with people and using GIS as a means to understand how urban squatter developments are organized, which in turn offers the foundation for devising improvement efforts.

"When visualizing squatter developments as cities within cities, GIS helps us see the internal connections that constitute the barrio's underlying order, which is fully perceived by the residents of the area," notes Giusti de Pérez. "To fully understand social networks within a community, planners need to obtain information directly from the community. Inhabitants have knowledge about who belongs to each social group and how social groups connect. This is valuable data with a geographic element."

Giusti de Pérez advocates an approach that recognizes the slum inhabitants as being deeply rooted in their communities. As people who have a sense of belonging, they are territorial and fear relocation plans. People want to remain where they have their social relations. Giusti de Pérez, who holds a master's degree in urban design, initiated an approach to developing urban planning models that includes input from residents so that squatter settlements can become an asset to the city. "We need to collect information that is significant to residents," says Giusti de Pérez.

With this thought in mind, Giusti de Pérez developed a framework for sustainable improvement planning with the ultimate goal of advancing the residents' quality of life. The objective of this planning approach is to introduce what she calls "friendly interventions" into the as-built environment. In this model, residents agree on behavioral and building rules, such as sharing waste disposal to maintain clean open space and limiting building height so as not to impede natural light. These are simple resolutions. Of course, squatter communities have much more complex issues, such as unstable slopes, inadequate utilities, and insufficient schools. GIS allows planners and residents to visualize the answers to the questions they are asking: What would happen if we put a concrete fascia on the slope? How can we run sewers into this area? Where is the best location for an elementary school?

Giusti de Pérez uses GIS to create what-if scenarios and generate maps that show what a concept would look like, whom it would affect, and how it would help. These images go a long way in providing information that engenders community participation in planning.

The maps that Giusti de Pérez and Ramón A. Pérez, a GIS professional, were creating in the 1980s using Esri's ARC/INFO began to be noticed. These GIS maps were instrumental in winning several national competitions against other urban planners who used CAD. Soon, several Venezuelan government institutions recognized that GIS is a clever tool.

"Barrio analysis is very complex," explains Giusti de Pérez. "GIS can take this mess of barrio data and organize it into something that makes sense. We would select a barrio, meet with its community leader, and explain that we wanted to help. The community leader would then invite other people from the community to a meeting, sometimes at a school or sometimes just on a slab made of some odd building materials. Together, we would identify what they needed and prioritize their concerns."

GIS was key to a three-year project in the barrio of Petare in Caracas to visualize and assess the area's urban built conditions and social networks. It proved essential to creating a sustainable planning strategy and for designing a development that fit both building and social needs within the conditions dictated by the geography of the site. With an ultimate goal of improving the quality of life, the urban planners worked with residents and identified 93 sectors within 82 hectares. Data included vehicular and pedestrian pathways, sector boundaries, social spaces, and built places. The group determined areas that were at risk for landslides and focused on building control policies for these areas.

Community concerns varied. In the Petare barrio, the community's main concern was accessibility to urban facilities and infrastructure. Residents wanted better drainage and solid-waste disposal. Priorities that were included on another barrio community's list were drainage, open space for children, and lighting. Each project was unique.

"Sometimes we can do a little and sometimes more," explains Giusti de Pérez. "We make our presentations using GIS, and people are glad to see what their community looks like. We use the ArcGIS 3D Analyst extension to create visualizations that show residents what their community could look like if they implemented changes. Based on community input and planners' assessments, we created site analyses that helped communities successfully request government program funding."

Proposed infrastructure systems for barrio Petare.

In 2008, Giusti de Pérez coauthored the book *Analyzing Urban Poverty: GIS for the Developing World,* published by Esri Press. In it, she and Ramón A. Pérez offer a step-by-step approach to working with squatter communities and improving their neighborhoods. The authors provide several rules for using GIS to support sustainable communities. One rule is to create procedures for involving communities in collecting the information required for identifying their problems and opportunities. This will help planners with the problem of lack of data. Another rule is to identify the social relations and interactions of the populations with the open spaces in the community. This is more important than merely describing land use. Finally, the authors advise using ArcGIS Spatial Analyst ModelBuilder in hilly squatter developments to understand the rules of urban and social functioning and identify steep slopes, drainage patterns, and accessibility from the neighborhood to the city.

Giusti de Pérez is hoping to expand the use of GIS models for urban redevelopment and promoting its capabilities to identify real, sustainable solutions for improving the quality of life for millions. She is truly a GIS hero.

(Reprinted from the Spring 2010 issue of *ArcNews* magazine)

Akron Housing Authority Streamlines Vacant Land Planning

GIS Supports Quick Analysis and Decision Making

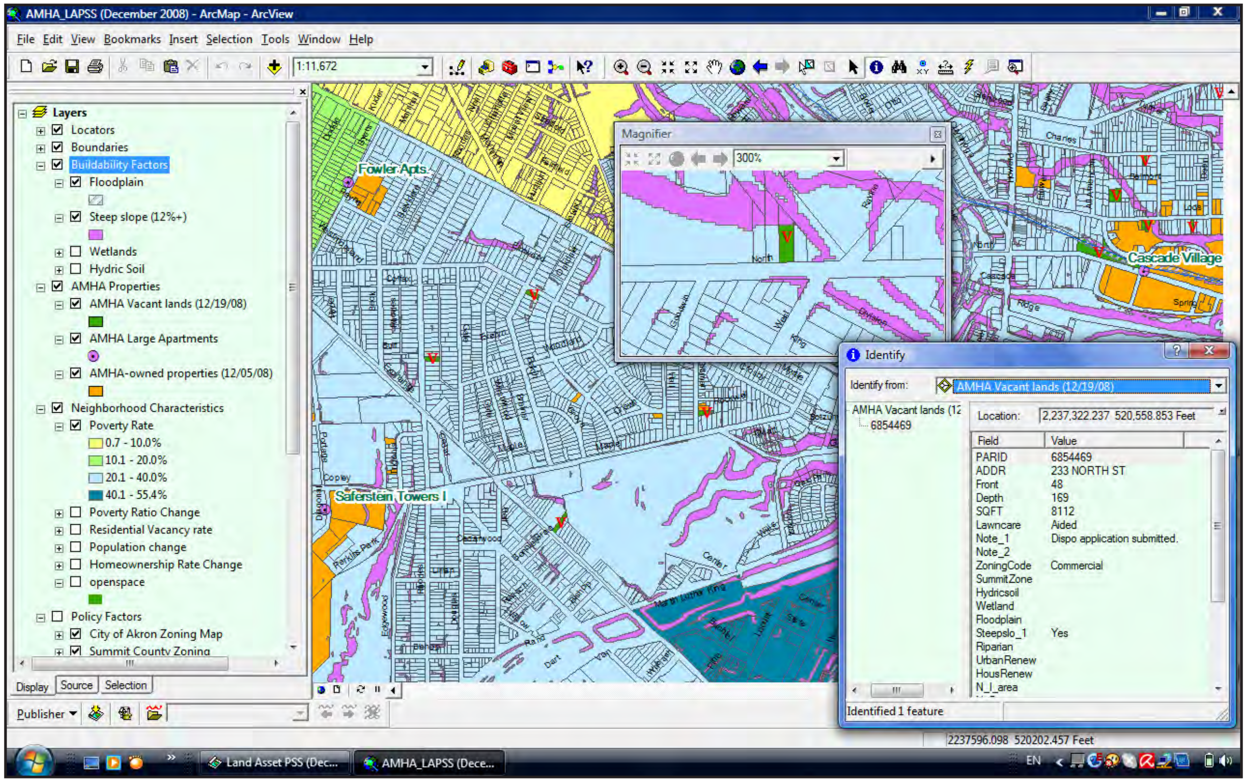
By Jung-Wook Kim, Planning and Development Specialist, Akron Metropolitan Housing Authority

Since 2001, the Akron Metropolitan Housing Authority (AMHA) has utilized Esri's GIS software for a variety of planning and administrative activities such as neighborhood, crime, and housing market analyses; resident relocation tracking; and site acquisition. It manages more than 4,700 public housing units and 130 vacant properties in Akron, Ohio. But it wasn't until 2008 that the authority began using its GIS in a systematic planning process when it launched a GIS-based land asset inventory project for managing its then approximately 250 vacant parcels. The GIS-based inventory has evolved into a GIS-based Land Asset Planning Support System (LAPSS) with a clearly defined planning process for managing the authority's vacant land.

The LAPSS contains the vacant parcel database and other GIS layers, which were obtained from the county auditor's property appraisal data and other public sources. The parcel-level information includes detailed site characteristics such as a parcel's size, dimensions, and adjacency to other AMHA-owned properties, with hyperlinks to on-site photographs and digitally scanned property records. Other layers are used to put the property information into a spatial context, including information on the parcel's environmental constraints (e.g., floodplain and steep slopes), neighborhood characteristics (e.g., poverty concentration and housing vacancy), and applicable public policies (e.g., the housing renewal plan and the city's capital improvement program areas).

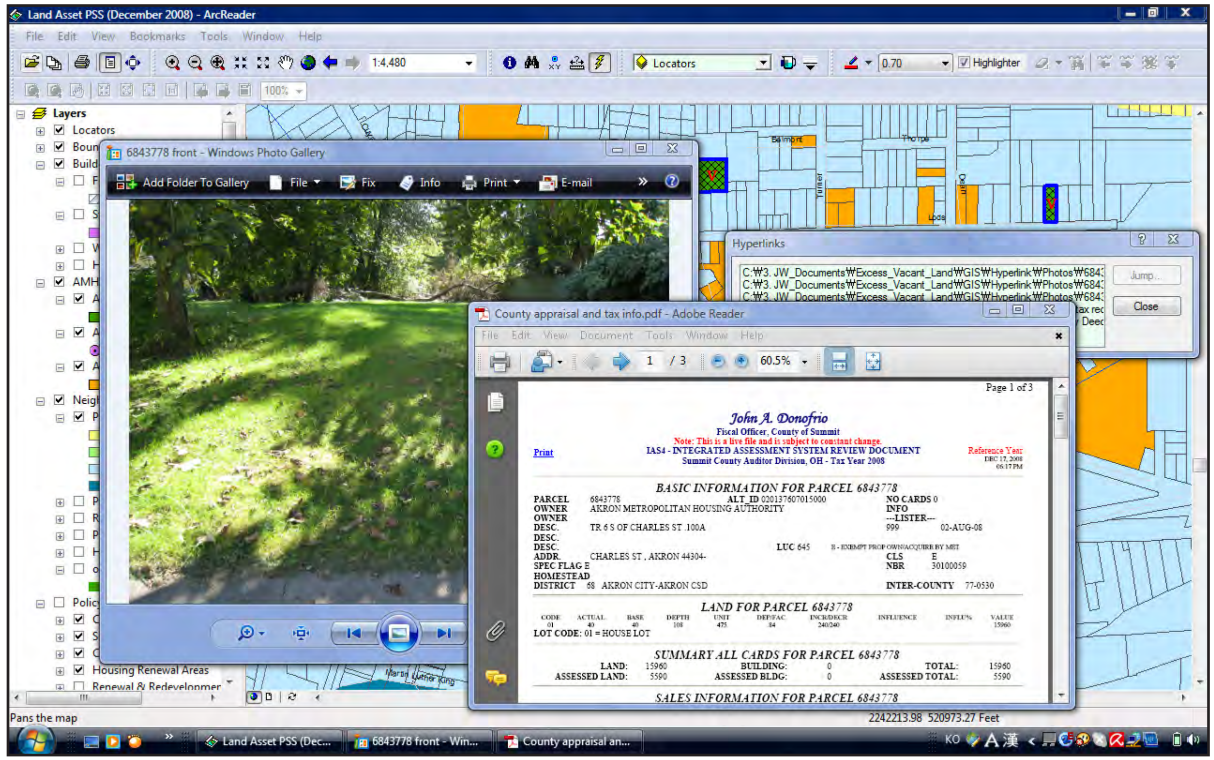
GIS overlays are used to identify parcels that are suitable for the construction of new housing. For example, the system was used to identify buildable parcels that were larger than a critical size, did not have large slopes, and were not located in a floodplain or wetland. The parcel-level information is combined with the neighborhood and institutional policy information and AMHA's policy goals (e.g., reducing the concentration of low-income areas and maintaining recreational areas) to provide a comprehensive view of AMHA's vacant parcels.

The LAPSS was initially used in a series of meetings attended by AMHA asset management staff to evaluate vacant parcels, 120 of which turned out to be nonvacant parcels such as parking lots and lawns. ArcGIS was used to display the information for each parcel on a large screen. The real-time visualization of the available spatial information allowed AMHA staff to quickly and easily review the information on each parcel and evaluate the implications of using different criteria to identify buildable and nonbuildable sites. The information was used to classify the vacant parcels into three categories—prime, secondary, and marginal—and develop a plan for holding, developing, or disposing of each parcel.



Planning information for more than 200 scattered vacant sites is shown in dark green including policy factors and site characteristics. Shown during an AMHA staff meeting, it improved land asset planning sessions.

The ability to interactively analyze and quickly and easily view the available spatial data allowed AMHA staff to engage in a series of highly informative and productive discussions. Information on the various sites that would have previously taken months to obtain on-site could be analyzed quickly and easily at AMHA headquarters. As a result of the meetings, it was decided that approximately one-fifth of the vacant land inventory should be sold to adjacent property owners, local governments, or community-based development organizations.



ArcGIS includes a free viewer that provides user-friendly GIS functionality for first-time GIS users on AMHA's asset management staff.

The easy-to-understand and lively visualization functionality that ArcGIS provided was unanimously praised by AMHA staff and leadership, who had not been familiar with GIS earlier. They particularly appreciated the time savings and the informative planning sessions that ArcGIS made possible.

The vacant parcel information was then used to prepare recommendations that were presented to the AMHA executive director. AMHA staff and leadership could review the vacant land information on their own using a free viewer for ArcGIS.

In addition to vacant land planning, the system is now broadly used for property data management, planning analysis, visualization, and data sharing. The spatial information has provided an extremely useful reference concerning AMHA activities such as preparing a property insurance policy, contracting for property maintenance, and evaluating property assessments, as all AMHA properties have been incorporated into LAPSS.

(Reprinted from the Summer 2010 issue of *Government Matters* magazine)

A Formula for Revitalization

Using Esri Business Analyst for planning project

By Matthew DeMeritt, Esri Writer

Hershey kiss streetlights line Chocolate Avenue.

Hershey, Pennsylvania, experienced a sudden and unexpected loss of visitor and resident patronage in its downtown. In 2008, Hershey Entertainment and Resorts, an entertainment and hospitality company dedicated to preserving the legacy of Milton S. Hershey, hired a GIS consulting firm to help attract consumers back to the area.

Retail trade area analysis is a necessary part of any civic development plan. To find a target market and gain knowledge about local consumers, geographic information must be carefully considered. Because GIS software specializes in extracting and aggregating geographic data, it is an ideal platform for conducting this analysis. Esri Business Analyst, which incorporates the Huff model (a tool for formulating and evaluating geographic business decisions), was instrumental to the process of successfully reenvisioning Hershey's downtown.

Location-Based Problem

The town of Hershey was originally designed by Milton S. Hershey to serve the needs of chocolate factory employees and their families. Built in the early 1900s, the original town included housing for factory employees as well as schools, churches, recreational facilities, and a trolley system. By the early 1930s, downtown Hershey had grown to become the center of activity for Hershey residents, with a bank, theater, department store, hotel, amusement park, and community center.

A statue of town founders Milton and Catherine Hershey on the campus of Milton Hershey School.

As the town grew and the number of visitors increased, Pennsylvania enhanced the local highway system to accommodate the increase in traffic volume. However, enhanced highways had the unintended effect of directing commerce away from downtown Hershey, enticing residents and visitors to shop in suburban shopping centers.

A New Vision

In 2005, Hershey Entertainment and Resorts drafted plans to revitalize the downtown. The revitalization effort started with the restoration of a prominent downtown building originally constructed in 1916 for printing candy labels. The newly renovated building opened in the summer of 2006 and is now home to two new restaurants on the ground floor, with the Hershey Entertainment and Resorts corporate offices occupying the two upper floors. Later, an interactive museum, the Hershey Story, was located adjacent to the renovated press building.

In 2008, Hershey Entertainment and Resorts contracted Delta Development Group, Inc., a community planning firm located in nearby Mechanicsburg, Pennsylvania, to conduct the next phase of revitalization. With design assistance from EDSA, a landscape architecture and urban design firm from Baltimore, Maryland, Delta began a yearlong process of creating a new vision for the downtown area.

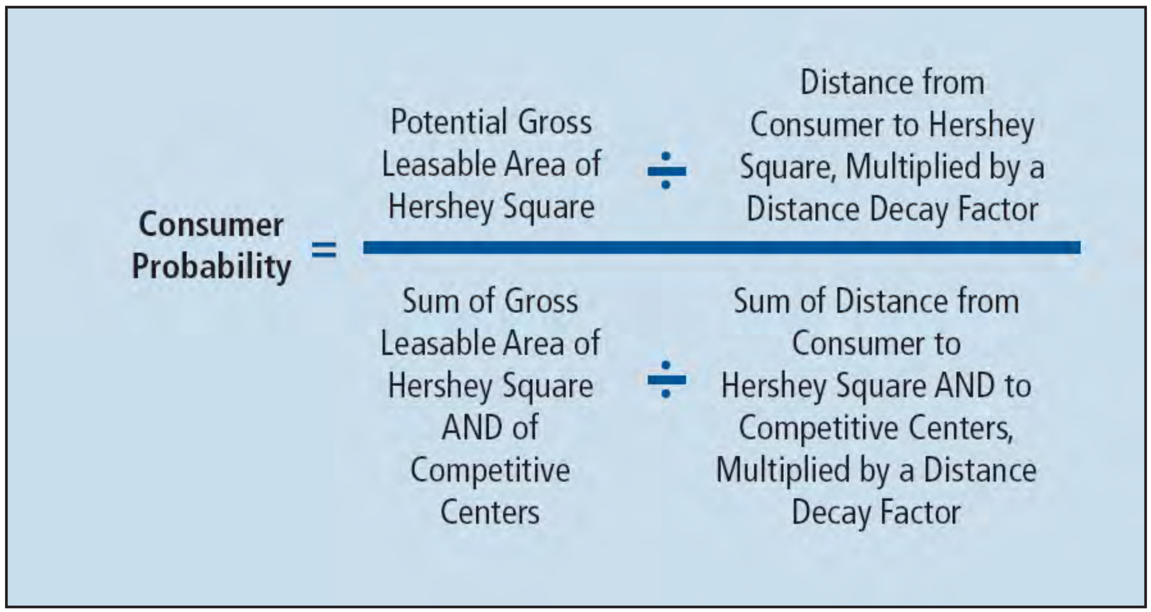
In keeping with Milton Hershey's original vision for downtown Hershey, the revitalization plan was based on the needs of the community while reestablishing a balance between the downtown and the surrounding resort, school, medical, and commercial areas. The goal was to make downtown Hershey serve the community so residents and visitors wouldn't need to go elsewhere.

Many Hershey factory employees reside in neighborhoods like this located in the town of Hershey.

An Integrated Formula

As Delta assessed the ability of Hershey's market area to support revitalization, EDSA evaluated the downtown's physical opportunities and constraints in preparation for creating conceptual designs. The ultimate challenge facing the team was creating a design concept with the right mix of appropriately sized uses clustered to capture the opportunities presented by the local market. The first phase of analysis would be to profile and measure the local market for real estate uses such as retail, residential, office, and public spaces.

In running demographic reports for comparative analysis, the most difficult task for Delta was determining the geographic trade area for downtown Hershey that would be used as a basis for estimating the amount of retail and restaurant space that could be supported. "The big question we needed to answer was, 'How far would people be willing to drive to shop and dine in downtown Hershey?'" said Debbie Tollett, senior associate at Delta Development Group. "To answer that question, we used the original Huff gravity model in Business Analyst." The Huff model is an analytical tool that measures the probability that a consumer will drive to a proposed new development site based on the distance they would have to travel to get there, the attractiveness of the development, and the area competition. It is assumed that the probability that consumer will travel to the site increases as the size of the site increases and as the distance or travel time for the consumer to the site decreases. *[The Huff model was developed by Dr. David Huff of the University of Texas and first published in 1963. To learn more about the Huff model, see "Parameter Estimation in the Huff Model" by David L. Huff in the October–December 2003 issue of* ArcUser *magazine.]*



The Huff model modified with Hershey-specific assumptions.

Once Delta established the geographic market area, it could conduct a more detailed evaluation of consumer spending and identify target retail tenants for further analysis. However, at this juncture, the analysis had focused on general retail spending. With an estimate from EDSA regarding the contiguous land area in the downtown that was available for development, the Delta team approached the analysis by assuming that this land could be developed into Hershey Square, a town center with leasable retail space that could compete with surrounding suburban retail centers.

The Hershey Press Building on Chocolate Avenue was recently renovated.

Bringing the Formula to Life

Applying Hershey-specific assumptions to the Huff model gave a clearer picture of the local market. Those assumptions and the Delta team's input for the model included the following five components:

1. The Huff model substituted Esri's census block group polygons as the "consumers" and used the estimated total annual consumer spending for retail goods from Business Analyst's demographic data as the data field to be summarized for each block group in the model results.

2. EDSA provided a preliminary assumption of the number of square feet that could physically be developed on the available contiguous parcels identified for redevelopment in the downtown area. This estimate represented the attractiveness factor, the potential Gross Leasable Area (GLA) of Hershey Square in the formula shown to the left.

3. Esri's shopping center data layer was used to identify and select competitive retail centers: the 14 retail shopping centers located within 15 miles of Hershey, including a 246,000-square-foot outlet center within a quarter mile of Chocolate Avenue. As with Hershey Square, the GLA field was identified as the attractiveness factor for the competitive centers in the above formula.

4. Business Analyst calculated the linear distance from each "consumer" to the proposed location of Hershey Square, and to each of the 14 competitive retail centers. These calculations are represented on the right side of the divisor in the formula.

5. Linear distance between consumers and shopping center locations represents only one distance consideration in the Huff model formula. The distance a consumer is willing to travel to shop is also influenced by other considerations such as the type of goods sought. For instance, consumers would be more likely to drive a longer distance to shop for furniture than to shop for groceries. The Huff model provides a distance decay constraint that can be entered in the model account for this factor. The appropriate constraint is entered as an exponent between 1 and 2. A smaller exponent represents shopping activities for which consumers will travel farther, such as furniture purchases. Since the Hershey model is based on total retail spending and represents a variety of types of retail goods, an exponent of 1.5 was used in the model assumptions.

Results: Local Market Defined

Based on these inputs and calculations, the Huff model provided spending probabilities by block group that allowed the Delta team to identify a defensible trade area. This resulted in a conceptual design and scale for downtown Hershey that was driven primarily by the local market.

While the Huff model requires the user to have at least a conceptual understanding of how the model works and how various input components impact the model output, Business Analyst's user-friendly interface allowed the Delta team to access precise analytic capability that would otherwise be outside the realm of its expertise. "Before discovering the Huff model operations in Business Analyst, I tried to do the equation on paper," laughed Tollett. "All the variables that need to be plugged into the formula ate way too much time. Performing the operation in an integrated environment made all the difference in getting the quick and accurate results we needed."

(Reprinted from the Summer 2010 issue of *ArcUser* magazine)

The UN's Global Urban Observatory

GIS Promotes Socially and Environmentally Sustainable Habitats

Highlights

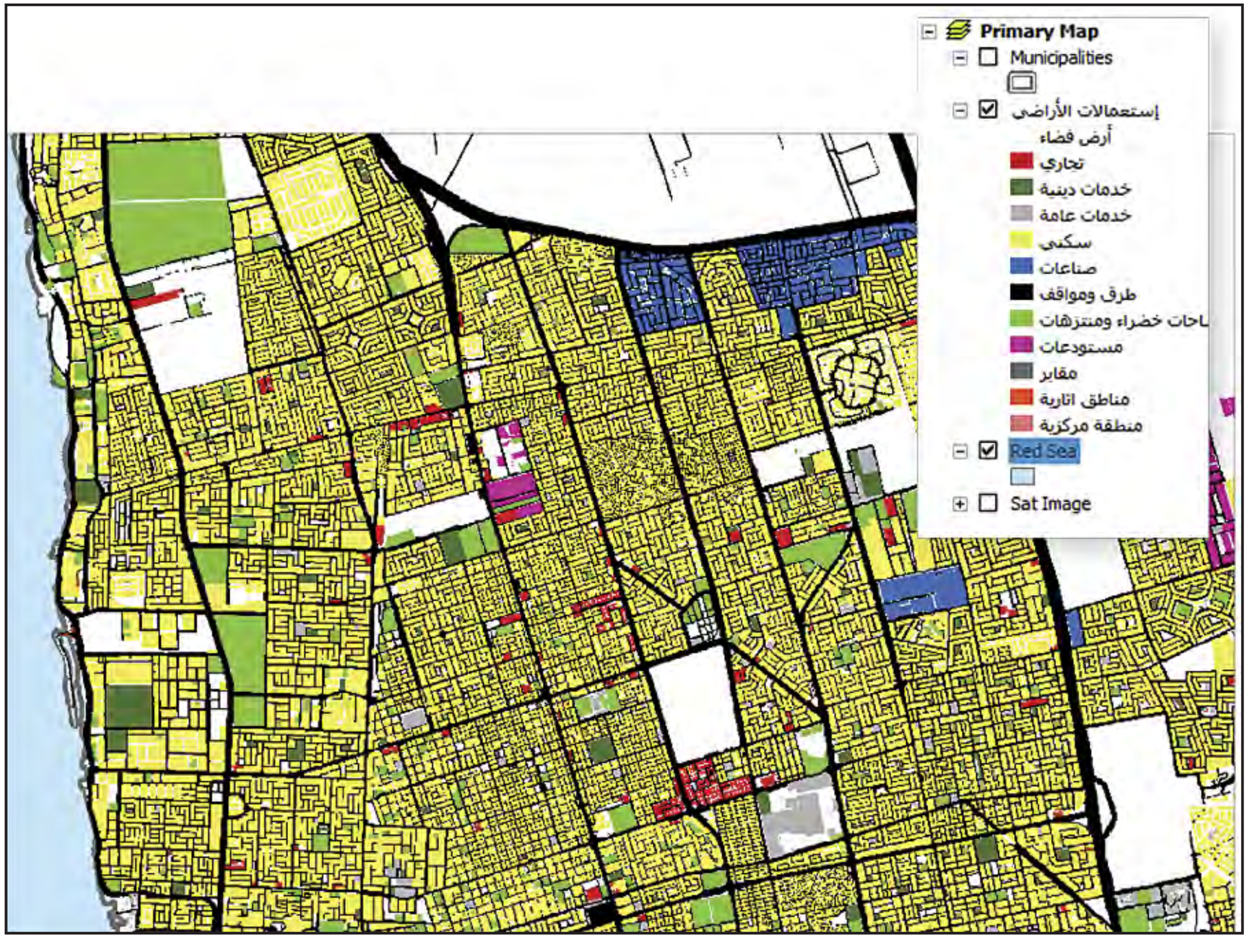
- Observatory monitors urban indicators.
- Policy makers use GIS to meet sustainable city objectives.
- UN-HABITAT adds urban observatory to Good Practice list.

In the last half century, the human population has grown at a phenomenal rate, leaving many of the world's cities bursting at the seams and often without the resources to care for their residents. From 1950 to the close of the century, earth's human population doubled. The United Nations (UN) estimates that one-half the world's population (an estimated 6 billion people) lives in cities and predicts that by 2050, two-thirds of the world's population will live in cities. It also notes that 50 percent of these urban dwellers live in slum conditions with little access to shelter, water, sanitation, education, or health services.

Because sustainable urbanization is one of the most pressing challenges facing the global community in the 21st century, the United Nations launched the United Nations Human Settlements Programme UN-HABITAT. Its aim is to help policy makers and local communities find workable and lasting solutions for developing human settlements. UN-HABITAT promotes socially and environmentally sustainable towns and cities with the goal of providing adequate shelter for all.

UN-HABITAT is building a worldwide urban knowledge base via its Global Urban Observatory that will make it possible to monitor and evaluate urban conditions and trends. This global endeavor is supported by a network of local urban observatories, which are designated workshops that develop monitoring tools used for urban policy making. GIS is proving to be a useful technology for monitoring economic, social, and environmental development.

The Kingdom of Saudi Arabia's cosmopolitan city Jeddah Municipality launched Jeddah Urban Observatory (JUO) to provide information for planning and policy making. ESRI Lebanon sal, Esri's distributor in Lebanon, designed a geospatial solution, built on ArcGIS, that improves the urban knowledge base by providing policy-oriented urban indicators, statistics, and other urban information.



This map shows land use in Jeddah City, Kingdom of Saudi Arabia.

Dr. Mohamad Abdulsalam, Jeddah Municipality's JUO chief supervisor and assistant to the deputy mayor for Environmental Affairs, notes, "The primary goal of building a GIS-based urban observatory is to use current data and ICT [information and communication technology] to effectively and efficiently disseminate among concerned decision makers and stakeholders information, knowledge, and expertise about a city's most current urban indicators, statistics, conditions, and profiles."

Staff can easily use JUO's GIS tools for spatial manipulation, simulation, and analysis and to display urban indicators. These indicators have spatial dimension. Indicators include variables of poverty, environmental degradation, provision of urban services, deterioration of existing infrastructure, access to secure land tenure, and adequate shelter. To date, JUO has generated 80 urban indicators and plans to define and generate 200 more.

The information technology infrastructure that supports JUO consists of two high-specification servers, 10 PCs, a local area network, and a high-speed DSL Internet connection. The GIS comprises ArcGIS Desktop and ArcGIS Server software. Through the use of Web-based GIS applications, JUO indicator data can be accessed and benchmarked at regional, national, and global levels. JUO has become the most important source of socioeconomic data in Jeddah.

GIS outputs help staff target need, monitor urban inequalities, assess the distribution of services, identify trends, and target resources for more effective allocation. For example, an adult illiteracy thematic map shows the percentage of male and female adults above the age of 15 who are illiterate. A transportation model displays various transport types within Jeddah's districts. A population density indicator map applies dots and graduated colors to show the population distribution across the city's districts. Although the GIS-based solution delivers advanced results, its tools are user-friendly, so it can be easily adopted by other Arab urban communities.

UN-HABITAT recognized ESRI Lebanon's JUO project by adding the unique information and monitoring initiative to its Good Practice list for cities to assess, identify, and monitor urban conditions. The performance of JUO is being monitored by His Highness Prince of Makkah Region as well as by Jeddah's mayor and municipality officials. "Jeddah citizens are truly the main beneficiaries of the project," concludes Manal El Sayed, ESRI Lebanon's GIS solutions manager, "as analysts and policy makers assess the extent of the city's problems and design the policies and interventions needed for achieving sustainable urban habitats."

More Information

Visit ESRI Lebanon at esrilebanon.com.

(Reprinted from the Spring 2010 issue of *ArcNews* magazine)

Building an Oasis in the Desert

GIS Helps Ensure that Masdar City Meets Its Carbon-Neutral, Zero-Waste Goals

Highlights

- Every facet of designing and building the city will be analyzed with ArcGIS.
- Asset management using ArcGIS means all systems can be visualized, maintained, and tracked efficiently.
- An enterprise geodatabase will be used throughout the city's life cycle.

Many of us are interested in decreasing our carbon footprint, whether one individual, one family, or one organization at a time. Imagine living in an entire city specifically designed to meet the ambitious goals of zero waste; sustainable living; and, ultimately, carbon neutrality. This is the vision of Masdar City, which is being designed and constructed in Abu Dhabi, the capital of the United Arab Emirates (UAE), by Masdar, Abu Dhabi's multifaceted initiative advancing the development, commercialization, and deployment of renewable and alternative energy technologies and solutions. *Masdar,* which means "the source" in Arabic, integrates the full technology life cycle—from research to commercial deployment. The Masdar company aims to create renewable energy solutions.

Masdar City is a prime example of how GIS can be used to design our future. This shimmering oasis of 6 square kilometers, located 30 kilometers from Abu Dhabi city, is committed to sustainable living. To reach its carbon-neutral ambitions, Masdar City will use only renewable energy sources. A photovoltaic power plant will generate most of the electricity, while the city's cooling will be provided via concentrated solar power. The zero-waste targets of Masdar City will be achieved through a combination of recycling, reuse, and some breakthrough waste-to-energy technologies. Landscaping within the city and crops grown outside will be irrigated with gray water and treated wastewater produced by the city's water treatment plant.

Through this innovative design, residents in Masdar City will consume far less energy. Peak demand at Masdar City is currently predicted to be only 200 megawatts instead of the 800 megawatts normally required by a conventional city of the same size and climate zone. Desalinated water consumption will drop from 20,000 cubic meters per day to only 8,000. And Masdar City will eliminate the need for millions of square meters of landfill.

This artist's conception shows an aerial view of Masdar City as it will look when completed.

The first residents of Masdar City will be the students and faculty of the Masdar Institute of Science and Technology (MI). MI is a graduate-level university specializing in alternative energy and environmental technologies and is a collaboration between Masdar and the Massachusetts Institute of Technology. MI will ensure a ready supply of highly skilled graduates to meet the growing demand within the clean technology and sustainable energy sectors.

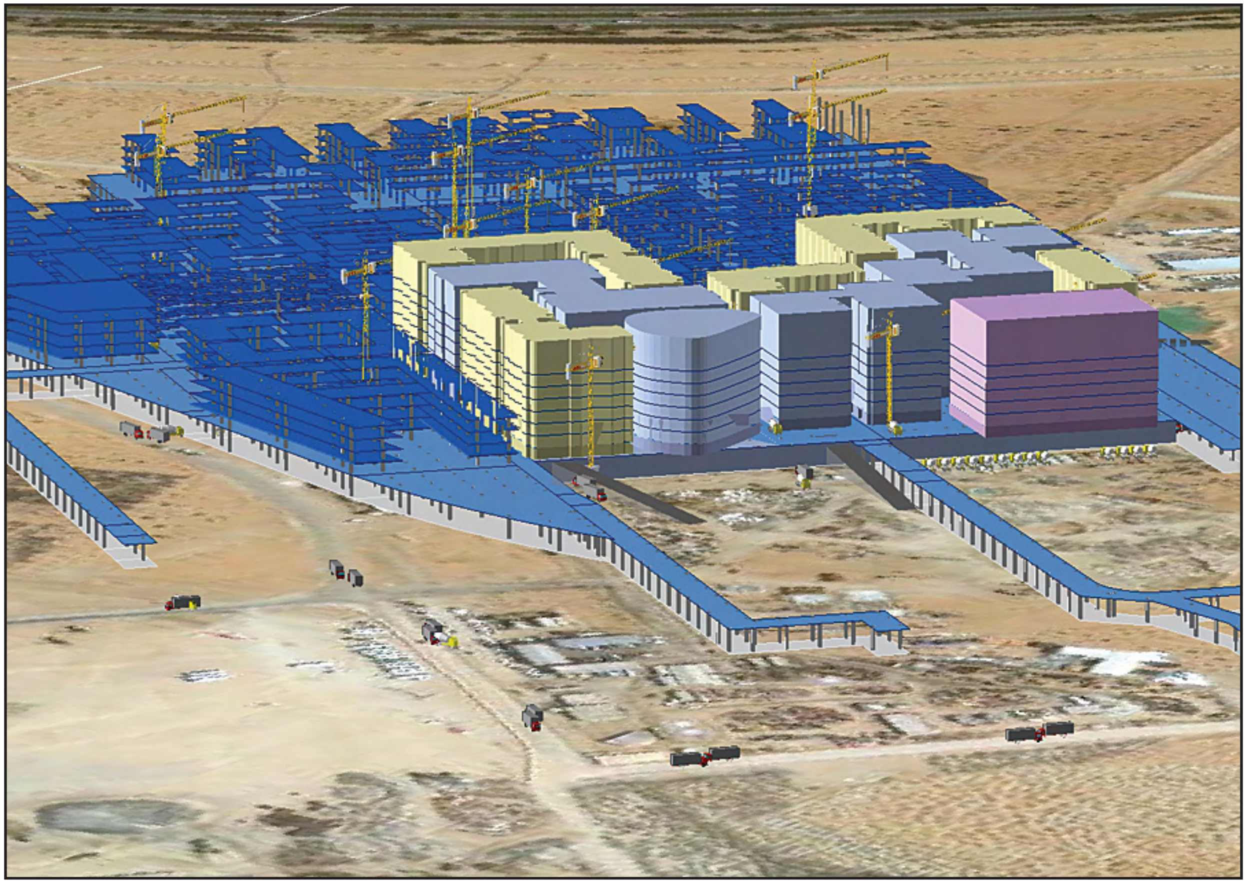
Shifting from Oil to Renewable Energy

UAE is a federation of seven emirates, or federal states, located in the southeast Arabian Peninsula. Abu Dhabi, the capital of UAE, has a rapidly growing economy, due largely to the emirate's vast oil reserves: Abu Dhabi is estimated to hold approximately 9 percent of the world's crude oil reserves.

Despite its vast hydrocarbon resources, Abu Dhabi has adopted a progressive approach to its economic growth. The emirate is committed to diversifying its economy away from oil, ensuring the long-term development and prosperity of the country. As a worldwide leader in the energy markets, the emirate believes it is well placed to invest its knowledge and financial resources in the world's future energy markets—renewable energy. So in April 2006, the Abu Dhabi government established Masdar. Through its portfolio of projects that includes carbon monetization, clean technology investments, and renewable utilities projects—both in Abu Dhabi and abroad—the company is contributing to the global effort of mitigating climate change. In this way, Masdar plays a key role in the development of Abu Dhabi's renewable energy sector, driving continual innovation and commercialization of clean and sustainable energy technologies.

Masdar's progress since its development has been significant. The company has established partnerships and large-scale renewable energy programs around the world. And as a further sign of Abu Dhabi's advancement in the alternative energy space, UAE was recently successful in its bid to host the headquarters of the International Renewable Energy Association, against strong European competition, in Masdar City.

CH2M HILL, an Esri Business Partner and a leader in full-service engineering and consulting based in Colorado, was chosen as a leading partner for the Masdar City design/build project. CH2M HILL had used Esri technology on many projects in the past and knew ArcGIS was the solution necessary to manage and analyze information throughout the city's life cycle.



Staff members at the City of Masdar use GIS to model building information throughout the life cycle of the project.

Lean, Green City Planning

"GIS is imperative in managing the overall spatial information necessary for designing, building, and operating Masdar City," says Derek Gliddon, GIS manager, Property Development Unit, Masdar.

For the city to meet its challenging goals, CH2M HILL carefully considered the geography of the area: sun angles, wind patterns, street widths, and building density and height. The orientation of buildings on a diagonal grid to provide maximum natural shading was modeled in ArcGIS. To understand all the variables and communicate effectively during the project, the company used a geodatabase that enforces use of a single, shared coordinate system across the project. A common basemap was created to support planning, design, and construction of the city, with the foresight that the city would also be maintained and operated using the same data.

"Building a city like this has never been done before. And GIS is proving to be an absolutely critical tool," says Shannon McElvaney, information solutions consultant, CH2M HILL.

Data layers contained in the geodatabase include information such as transportation, vegetation, drainage, structures, boundaries, elevation, biodiversity, buildings, and utilities, as well as terrain elevation, bathymetric data, and remotely sensed imagery. Information from tabular databases is incorporated into the map layers, as well as GPS coordinates and georeferenced photographs. All the construction-related information, including cost, schedule, and carbon tracking data, is tied together by location, making it more accurate and efficient to use.

The resulting information is available company-wide. ArcGIS Server was recently deployed and will enable the more than 100 organizations involved in developing Masdar City to access maps, data, and analytic services, thus reducing problems of multiple data versions in circulation. A sophisticated Web browser-based virtual city visualization and navigation tool uses master plan data from the geodatabase and links to the program scheduling software. This tool is used to visualize the construction of the city over time. Construction managers can navigate anywhere in the city; "play" the project timeline; and identify spatiotemporal clashes, accessibility problems, and other logistical issues. On a fast-paced, high-density development, these issues are very important. Information can be searched using spatial criteria and viewed on easily readable thematic maps. Using GIS to visualize the massive amounts of data makes communicating about the project easier.

Optimized Facility Placement

ArcGIS introduced the spatial analysis and modeling necessary for the most efficient placement of facilities at the city. Water and sewage treatment plants, recycling centers, a solar farm, geothermal wells, and plantations of various tree species were placed using traditional planning principles modeled with ArcGIS. Questions—Is there enough physical space available? How much are the buildings shading each other? How much space is needed between a facility and the residents?—are modeled and the best answer chosen through GIS.

McElvaney cites a problem that was quickly resolved when line work from one building was off by 30 centimeters from the previous line work. Having access to all the data and visualizing it with GIS allowed catching the mistake: "A mistake like that could be very time and cost intensive to fix during the construction stage. GIS is extremely helpful in preventing that kind of thing from happening."

From Models to Real Life

GIS has ensured that the carbon-neutral status of the city translates from a concept to design. CH2M HILL used ArcGIS to even choose where to place construction materials during the building phase. Alternative scenarios for where to place building materials could be modeled so that, in the end, the company could choose the most efficient location for reducing transportation-related carbon emissions.

GIS was able to model water and power usage over a period of 10 years, plotting monthly resource demand across the city like a geographic histogram. The variables appear as different heights, allowing planners to see any issues rapidly. "This exercise immediately revealed a couple of problems with the logic that had not been easy to spot in a massive spreadsheet format," says McElvaney.

Changes happening during construction were tracked and recorded to monitor the effect on carbon neutrality. Masdar City has a team that keeps track of all fuel and material use and reuse during building. This team is also responsible for logging any environmental infractions. Team members found that using a GPS-enabled camera to take photos and transfer them to the GIS to document the location of an infraction allowed them to see what happened where and whether there were underlying trends, all of which contribute to managing the sustainability of the build.

Innovative Transportation

Masdar City will utilize breakthrough transportation technologies that revolutionize and redefine urban transport. A Personal Rapid Transit (PRT) system running on solar-charged batteries will transport residents around the city. There will be 3,000 PRT vehicles, generating 130,000 trips each day across 85 stations. A Freight Rapid Transit system will make up to 5,000 trips per day to transport the city's goods. ArcGIS was instrumental in visualizing all routes for the PRT network and testing predicted walk times between PRT stations. Transportation planners also used ArcGIS to find optimal locations for perimeter parking garages, along with effective road and rail transport routes into the city. Real estate plots were valued using routing GIS.

Beyond Construction

Conventional cities of similar size create approximately 1.1 million tons of CO_2 per year—80 percent from buildings and energy creation, 13 percent from waste, and 7 percent from transportation. Masdar City expects to eliminate the emissions by producing zero carbons. ArcGIS will continue to be used and integrated with a computerized maintenance management system that will include the location of all infrastructure assets; gas pipes; smart grid infrastructure; clean, gray, and black water networks; and the transportation network. Moving forward, GIS will make facilities maintenance easier and enable the tracking of resource use and reuse and the overall carbon balance of the operational city. GIS will be used in city governance, where it will form part of the city's sustainability performance feedback service, which will inform residents about their personal contribution toward overall city performance.

(Reprinted from the Fall 2009 issue of *ArcNews* magazine)

Mobile GIS Improves Code Enforcement Services in McAllen, Texas

By Brian Wienke, Product Manager, Accela, Inc.

Code enforcement is critical to a city. Monitoring violations of municipal codes and land-use requirements helps maintain a safe and desirable environment. Faced with a growing workload and reduced revenues in 2006, the code enforcement department in the City of McAllen, Texas, began looking for ways to increase its efficiency and productivity. The solution was mobile GIS.

Prior to the implementation of its mobile GIS, the city relied on a paper-based process that required code enforcement officers to spend valuable time in the office checking several different Web sites to gather accurate owner, parcel, and address information prior to actually going out in the field to perform their inspections.

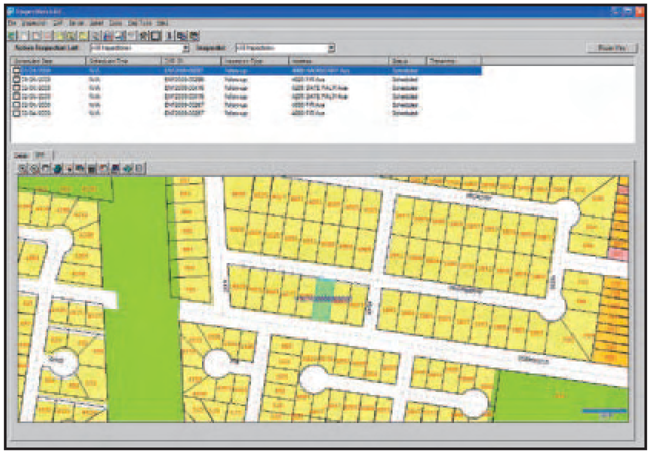
To correct the inefficiencies of its antiquated paper-based system, the city conducted a workflow analysis that led to the development of an automated system for tracking code enforcement cases.

Based on this success, the city decided to automate the entire process and selected a Web-based solution that included Accela Automation from Accela, Inc. This local government software suite automates a number of daily tasks including workflow management, activity tracking, and report generation.

To extend the functionality of Accela Automation across the enterprise and out into the field, McAllen also implemented Accela Wireless, which is built with the Esri ArcGIS Server mobile ADF technology fully embedded within it. With this fully integrated, enterprise-wide solution, the city began to realize significant improvements in its code enforcement services.

The mobile GIS enables workers to display, inspect, capture, and update geographic information from the field. Collected data includes address, owner, and parcel information; zoning classifications; and physical locations within city limits. Field officers can also file code enforcement cases to speed up data delivery, and the system allows one officer to easily follow up on the status of an inspection or Notice of Violation performed by another officer.

McAllen's mobile GIS solution enables code enforcement officers to utilize fully functional maps and perform updates in real time, which streamlines their administrative processes and enables faster customer response times.



With mobile GIS, inspectors can quickly locate their inspections, select parcels on the map, and create new inspections or cases from the field.

"Now the code enforcement process is more accurate and efficient because everything is available in one solution rather than having to go to different sources for the data," says Jose J. Peña, McAllen project manager. "Our officers have also gained experience with navigating the city's GIS Web site, which they had previously only used occasionally. The new mobile implementation not only met but exceeded all our expectations."

Among the benefits the city has realized are improved response times, an increase in cases handled, and greater staff efficiencies.

"We processed about 5,000 code enforcement cases in 2007 and about 9,000 cases in 2008 after implementing the new system," says Peña. "We wouldn't be able to keep up without the ArcGIS Mobile capability in the mobile solution. Case completion is much faster and makes our officers more efficient, accurate, and accountable for the cases we are working on."

Recently, McAllen's building inspectors also started to use the mobile GIS solution. They find it extremely beneficial to see inspection locations on a map rather than using an address and directions to find a site. Other mapping applications are on the horizon for the city's planning and development departments.

Inspectors use GIS maps and data to obtain additional information, such as address and parcel relationships, and other attributes, while performing their inspection tasks.

"The mobile GIS solution is practical and useful and has a direct impact on the quality of service we can provide to the community," concludes Peña. "We are able to visually examine the spatial distribution of cases throughout the city, giving us a new perspective on the work being done by our code enforcement officers. In addition, it helps us better determine if each section of our city is being properly served."

(Reprinted from the Winter 2009/2010 issue of *Government Matters* newsletter)

Mapping Urban Inequalities with GIS

By Linda Loubert, Economics Department, Morgan State University, Baltimore, Maryland

Highlights

- ArcGIS is used to geocode 911 calls and crime data to socioeconomic and demographic data to determine a focus/study area.
- Esri Business Analyst mapped all businesses around a proposed emergency shelter site.
- GIS is important to homelessness prevention.

Mapping urban areas can help cities target policies that are most efficient and effective for their communities, particularly for those who are less fortunate. However, finding a solution to a problem such as homelessness entails understanding the associated issues. GIS has become fundamental to that process.

Homelessness prevention, of course, should be the first priority. But when that has not taken place, it becomes necessary to have a structure ready to supply fundamental care and services. Finding a location for shelters gets to be a tricky situation for local governments because businesses find it undesirable to have homeless people close by and, therefore, resist their accommodation, hoping shelters will not be near their businesses or, as the slogan goes, Not in My Back Yard (NIMBY).

Social scientists at Morgan State University, Baltimore, Maryland, studied the impact of locating a permanent homeless shelter for the City of Baltimore with the intent of uncovering all perspectives of building a new structure. Their findings could be applicable to any city. Beginning with some statistics on homeless people, the study found a clear indication of the critical need for some type of permanent structure because

- More than 800,000 people may be homeless on any given day; 200,000 of them may be children (Burt, M. R., 2001. *What Will It Take to End Homelessness?* Washington, D.C.: The Urban Institute).
- During a typical year, 900,000 to 1.4 million children are homeless.

- Ten percent of all poor people may be homeless, even if only for a short while.
- Seventy-five percent of homeless individuals access services in central cities (*The Annual Homeless Assessment Report to Congress*, 2007).

When more than 50 percent of their income has to go for housing, this tends to push low-income people into homelessness even faster. Also contributing to the problem is that U.S. health care policies have removed institutional support for people with severe mental illness, along with a drastic reduction in long-term hospitalization for the mentally ill; this has pushed these individuals out into the streets.

The "visible" homeless people are generally overrepresented in central cities of large urban areas. In Baltimore, as in other cities, homelessness is a serious social and public health problem, so the city believed building a new emergency shelter for more than 200 people would help alleviate some of the problems for homeless individuals. Building the shelter, called the Housing Resource Center, is a strategy to address the City of Baltimore's 10-year plan to end homelessness. This project reflects various aspects of best practices to the extent that it integrates a 24/7 emergency shelter with an array of supportive services (health, counseling, and employment).

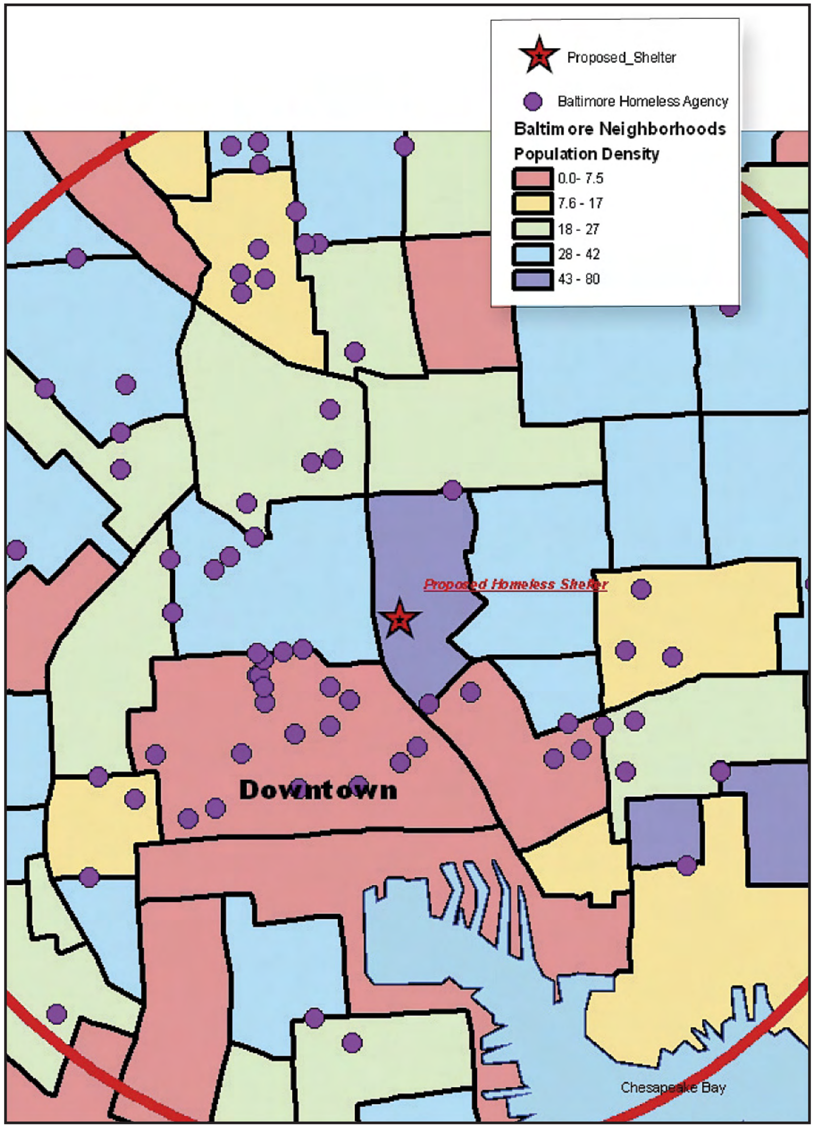
The study involved key stakeholders to understand the impact of this shelter as it related to homeless people, businesses, service providers, and neighborhoods located less than one mile from the proposed site. The study also included the developers of buildings for homeless people who could contribute design ideas that would incorporate safety measures for the shelter residents and the residents of the surrounding community, as well as appropriate architectural designs for the area.

ArcGIS was used by the Institute for Urban Research at Morgan State through an Esri university site license. Using its overlays and tools, the institute's researchers incorporated ArcGIS in this study beginning with community mapping; they collected information from the city, local businesses, and neighbors of the proposed site. They captured mobility patterns of homeless individuals using GPS. ArcGIS provided the tools to geocode 911 calls and crime data to U.S. census block groups, and socioeconomic and demographic data from the U.S. census was added to paint a picture of the focused area for analysis. The researchers took population density into account for defined neighborhood boundaries and the location of current service providers within a 1.5-mile radius (showing at least 60 percent of the providers of services to the homeless).

It should be noted that the City of Baltimore has only used temporary emergency shelters, scattered throughout the city, not a permanent one. Even though the neighborhood is densely populated, the study showed that the proposed location of the site would be in an unpopulated area of the neighborhood, under the viaduct of an interstate highway.

With Esri Business Analyst, all businesses around the proposed site were identified. Businesses in the neighborhoods surrounding the proposed emergency shelter represent 13 percent of all businesses in the city. The area consists of the downtown district.

From this kind of study, the question naturally arises: Will the shelter bring more crime and/or disturbances? To answer this question, researchers geocoded emergency medical services (EMS) calls and other crime data to U.S. census block groups for 2004 and 2008. Since a private sponsor



This shows the population density for defined neighborhood boundaries and locations of current service providers within a 1.5-mile radius. Within this radius are at least 60 percent of the providers of services to the homeless.

opened a multipurpose soup kitchen in 2007, within 1,000 feet of the proposed facility, the homeless traffic was assumed to have increased during that time; this gave good reason to use years 2004 and 2008 for analysis of crime and EMS data. Based on standard deviations, the results indicate that the proposed site would not increase crime with an influx of more homeless people.

The study concluded that businesses and neighboring communities possessed a rather negative view of having a permanent shelter in their area. Homeless people were seen as loiterers and panhandlers who sleep in public spaces and relieve themselves on private property and who should not be concentrated in one area of the city. Service providers and developers perceived homelessness as a societal health illness, with the need for compassion and effective policy to relieve the symptoms. The homeless individuals who spoke during the focus group study indicated that their desire for help was only for private residency, not group residency, as the proposed structure would provide.

Using ArcGIS Desktop and Esri Business Analyst, the study concluded that the site would be in a sparsely populated area of a few blocks within a densely populated neighborhood that included some businesses. The crime and EMS data showed that no increase in crime would occur because of the site when standard deviations were examined.

Using GIS along with qualitative analysis, such as the focus group of stakeholders, cities can better understand the needs of the homeless population.

About the Author

Linda Loubert, Ph.D., is an assistant professor in the Economics Department at Morgan State University, Baltimore, Maryland, and an affiliate researcher in the Institute for Urban Research at Morgan State.

More Information

For more information, visit the Institute for Urban Research at iur.morgan.edu. Other key personnel for this study from Morgan State University were Mary Anne Akers, Ph.D., School of Architecture and Planning; Jonathan VanGeest, Ph.D., School of Community Health & Policy; Sidney Wong, Ph.D., School of Architecture and Planning; Azza Kamal, Ph.D., School of Architecture and Planning; and Marvin Perry, Office of Sponsored Programs.

(Reprinted from the Spring 2010 issue of *ArcNews* magazine)

Locating, Appraising, and Optimizing Urban Storm Water Harvesting Sites

Central Business District of Adelaide, South Australia

By Matthew D. Shipton and Sekhar V. C. Somenahalli

Highlights

- GIS is helping make South Australia more drought resilient.
- GIS is used in the creation of strategic water resource plans.
- Specific storm water harvesting benefits are identified and maximized with GIS.

Storm water is surface water runoff generated from rainfall. It is created when rainfall intensity exceeds infiltration capacity. This often occurs when rain falls on hard, impermeable surfaces, such as footpaths, car parks, and roads. In urban areas, this water then typically flows untreated via storm water drains into local watercourses.

Harvesting collects and stores storm water before it enters natural environments so that it can be reused at a later time as an alternative to water from water mains. Before it is reused, captured storm water may be treated to improve its quality. Recycled storm water is typically used for nonpotable demands that do not require a high level of treatment, for example, irrigation, toilet flushing, car washing, and certain industrial and commercial uses.

Harvesting storm water reduces the detrimental impacts that urban development can have on rivers. It reestablishes more natural river flow regimes and improves the quality of the water in rivers. In addition to the environmental benefits, storm water harvesting can also be financially attractive to both its suppliers and users. Harvesting storm water reduces demand for water from water mains, delays the need for major new water resource infrastructure, increases water security, and has low pumping costs since the source is often close to the point of use (i.e., it is generally harvested and used in the same urban area).

Storm water harvesting areas modeled in proximity to public roads.

Storm Water Harvesting and GIS

Though beginning as a master's research project, the study described below was extended by the University of South Australia, through its Esri site license, to include detailed hydrological modeling of individual storm water schemes. The team performed this analysis using the Environmental Protection Agency specialist storm water modeling GIS (EPA SWMM). The objective was to verify claims made in the South Australian government's Water for Good plan, with results to be published later in 2010.

This study demonstrates the value of GIS to storm water managers through the assessment of harvesting opportunities in the central business district of Adelaide, South Australia. Adelaide is the largest city in the driest state in the world's driest inhabited continent.

Data used in the study was obtained from various sources, including the Australian Bureau of Meteorology; the South Australian Department for Environment and Heritage; the South Australian Department of Planning and Local Government; and the South Australian Department of Water, Land and Biodiversity Conservation.

The team members identified areas suitable for storm water harvesting in ArcGIS Desktop by analyzing land cover, land use, and topography. They defined suitable areas as having

- Predominantly impermeable surfaces, such as concrete or asphalt pavement
- An appropriate land use (that is, one that did not pollute the quality of the runoff from that area)
- A natural drainage pattern that facilitated the collection of storm water from a large area without significant earthworks

First, the team defined each part of the study area as permeable, semipermeable, or impermeable. This categorization was derived from a reclassification of detailed land-use data based on assumptions regarding the average permeability of each land use. The output was then refined using local site-specific information, Normalized Difference Vegetation Index (NDVI) data, georeferenced aerial photography, and the Digital Cadastral Database (a source of legal land parcel data that, among other things, contains data on roof materials). The refinement allowed corrections, such as the alteration of the botanic gardens from being defined as impermeable—because its land use was public institution—to being permeable, based on its high NDVI and land cover as determined by aerial photography.

Next, the team identified all the roads and the areas in proximity to them in the study area. It was assumed that storm water runoff in these areas would be particularly polluted by contaminants from cars. These contaminants would likely include heavy metals, hydrocarbons, particulates from vehicle exhausts, debris from tires and brake linings, ultrafine platinum from worn catalytic converters, and lead salts from batteries. Most of the roads in Adelaide's central business district are laid out in blocks. Each side of the main blocks is 150 meters long. Areas in proximity to roads were defined as being less than 60 meters from a public road, since this is slightly less than half of 150 meters. The areas identified by the buffer that were more than 60 meters from a road were then intersected with the previously described impermeable areas layer. This procedure identified 245 separate areas that were impermeable and not close to a road. From these potentially suitable areas, sites that were less than 100 square meters were excluded on the grounds that they would not be economically feasible for harvesting storm water. This reduced the number of potentially suitable sites to 28.

Then, the team spatially joined information from a digital elevation model (DEM) with a 3-meter resolution to the polygons representing the 28 remaining potentially suitable sites. This enabled the average slope across each site to be calculated. Sites with a greater slope would generate more runoff per unit area per unit of time. The DEM was also used to define the main catchments and subcatchments in the study area (using the Arc Hydro extension). The team members calculated the number of subcatchments that each of the 28 potentially suitable sites covered. The number ranged between one and four. Those covering one subcatchment were deemed better suited to storm water harvesting since surface water runoff in them would drain to a single point.

The team ranked the suitability of the 28 remaining sites and visited the 10 most suitable sites to confirm if harvesting could be done within the available space; would not negatively impact existing land uses; and would be practical, given the local topography and existing drainage infrastructure. This process led to the removal of sites, such as cemeteries, that would be inappropriate for storm water harvesting.

Among the remaining potentially suitable sites, there were two that were highly suitable. These were the grounds of Adelaide Festival Centre and the land occupied by the University of South Australia's City East Campus and the main Adelaide University City Campus. These two areas are not highly permeable, less than 100 square meters, close to roads, or flat.

The next task using GIS was to examine if and how the most suitable harvesting sites could be connected by storm water infrastructure to form one storm water harvesting scheme. This would have economies of scale, since the project would then only require one treatment and storage solution. This task was completed using EPA SWMM.

Once the infrastructure layout of the optimal scheme had been determined, the team used EPA SWMM to model each of the harvesting sites' vulnerability to flooding after heavy rainfall. EPA SWMM was also used to determine the likely impact of climate change (reduced rainfall) and urbanization (increased impermeable area) on harvesting yields at each of the sites.

Conclusion

In South Australia, storm water harvesting is increasingly regarded as an untapped, sustainable water resource. This study demonstrates how GIS can be used to plan storm water harvesting schemes at both a strategic level by way of options appraisal and at a design level via hydraulic simulation. GIS provides decision makers with information that enables them to maximize system performance (storm water yield), economic feasibility (payback period), and public acceptability of harvesting schemes while reducing environmental degradation (caused by polluted storm water) and risks to public safety.

The GIS modeling undertaken with ArcGIS Desktop, Arc Hydro, and EPA SWMM in this study identified a number of potentially suitable areas in Adelaide's central business district that could be used as storm water harvesting catchments. A simulation of a harvesting scheme that used four of the most appropriate catchments found that 330 ML of reusable storm water could be collected every year. This finding should be interpreted with due regard for both the untreated quality of the harvested storm water and the irregular timing at which it would be available.

About the Authors

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County Health Department Makes Brownfield Environmental Data Accessible

By Barbara Shields, Esri Writer

Elkhart County, Indiana, uses Esri's ArcGIS software to map brownfield or Superfund sites, industrial areas that must be environmentally evaluated before qualifying for reuse.

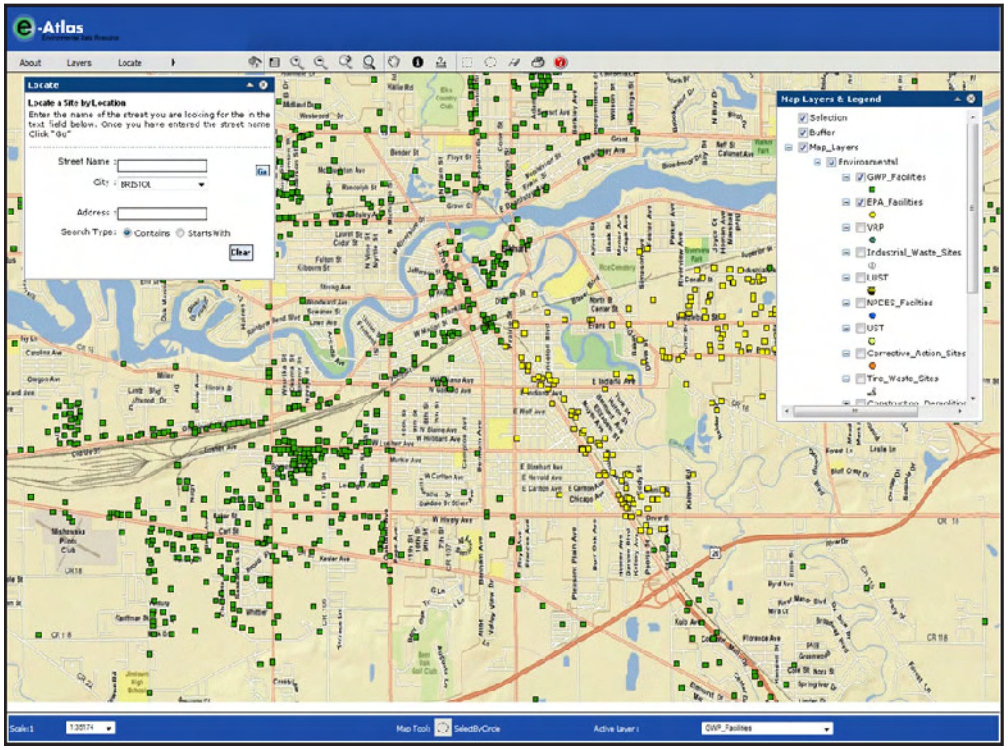
Closed factories can be toxic and lower adjacent property values.

This helps county personnel and the public understand the histories of brownfield sites and rate their risk and impact to the environment. Elkhart County Health Department asked Symbiont, an engineering and consulting firm headquartered in West Allis, Wisconsin, to help expand access to the county's database and create a public Web site that allows citizens to search for data on hazards at brownfield sites, such as leaking underground storage tanks; see the data associated with a map; and locate potential at-risk areas. The health department dubbed the application e-Atlas.

Data is key to a successful environmental management program. For more than 20 years, Elkhart County built a paper-based database to support its Groundwater Protection Ordinance program. The program's purpose is to prevent water resources from becoming contaminated by industrial chemicals.

Properties designated as brownfields are ugly and dangerous and can threaten the community's health.

In 2006, the county decided to reduce urban sprawl by redeveloping its brownfields and other underused sites and existing infrastructure. It applied for an Environmental Protection Agency (EPA) brownfield assessment grant and was able to create a map-based electronic data management solution. Symbiont and Elkhart's geographic information system (GIS) team went to work designing a brownfield inventory. For the foundation of the inventory database, the team used existing county groundwater protection data. This contained property information of facilities that used or stored hazardous materials as well as the environmental records of the most contaminated and neglected sites. The database inventory scope spanned 20 years for 5,000 facilities.



Elkhart County's e-Atlas, built on ArcGIS Server, is a Web-based brownfield inventory tool that shows environmental concerns such as abandoned facilities, leaking underground storage tanks, and tire waste sites.

Converting the Files

Faced with 44 file drawers filled with inspection records and reports of complaints and state and federal actions, along with correspondence and miscellaneous information, the team converted 200,000 pages of paper-based records to digital format. The conversion process involved defining an index structure for cataloging and digitizing records. The documents were integrated with GIS by geocoding the facilities by their addresses.

Another step in the conversion work process was to put the records online. The team used Esri's ArcGIS Server technology to create a Web application that combined the inventory databases with GIS for mapping and analysis. This makes it possible for a visitor to the Web site to research a facility by selecting it on a map and clicking links to the facility's database records. The application makes it easy to view and research the data.

The value of a geodatabase for a brownfield analysis is the accumulation of geological data, such as slope, soil porosity, and hydrology; information about the presence of chemicals, wells, and tanks; as well as site usage histories such as waste producing industrial facilities. With GIS, all these environmental attributes can be visualized on a map.

Better Access and Usability

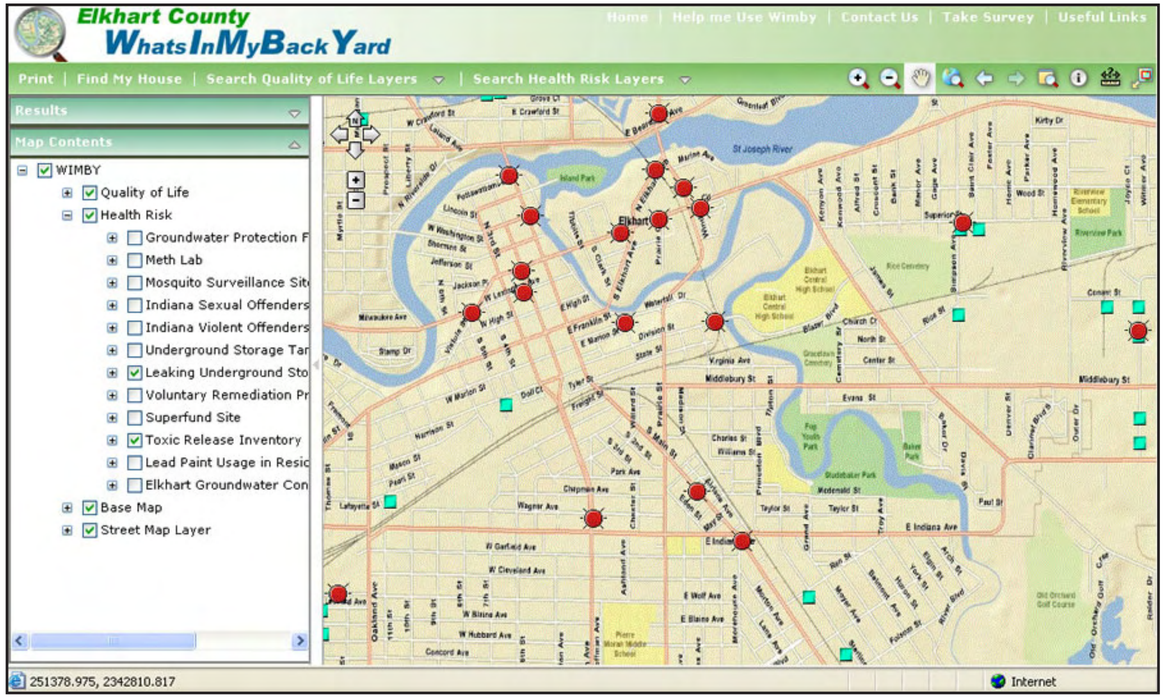
The system conversion has improved Elkhart's Groundwater Protection Ordinance program because GIS allows a community-wide picture to be generated. Health Department staff can easily pull up data layers about current land use and the proximity of community well fields to quickly see where water resources might be threatened. Facility relocations and transitions can also be managed to provide the appropriate frequency of inspections. Queries can be conducted to determine the need for inspections by township or municipality, thus improving time management in the program.

Staff time spent locating documents and records has decreased. What once took hours of searching through files now takes seconds in the GIS. The user types in an address or selects a location on the map and receives in-depth information about that location. The user also can run a query that brings up all similar sites or overlay data layers to easily view relationships. These capabilities set the foundation for putting GIS to work for a host of other county projects.

GIS is useful for site remediation to see underground and aboveground tanks, stained soils, and other site hazards.

The e-Atlas application is accessible to the public via Elkhart's What's in My Backyard (WIMBY) Web portal. Here, citizens can get online, map-based information that shows community brownfields as well as other threats to the community. WIMBY helps the Health Department communicate with the public and provide information needed for EPA grant requests.

"GIS delivers an accessible brownfields inventory that really helps our customers with their EPA grant applications," says Ryan Eckdale-Dudley, Symbiont's GIS coordinator. "They can easily bring up information required for creating a case that qualifies them for project funding."



WIMBY gives the public access to information for evaluating potential health risks in Elkhart County communities. This map shows leaking underground storage tanks (red dots) and toxic release inventory sites (green squares).

Learn more about Esri's GIS solutions for brownfields management at esri.com/brownfieldsgis.

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Since 1969, Esri has been giving customers around the world the power to think and plan geographically. The market leader in geographic information system (GIS) solutions, Esri software is used in more than 300,000 organizations worldwide including each of the 200 largest cities in the United States, most national governments, more than two-thirds of Fortune 500 companies, and more than 5,000 colleges and universities.

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