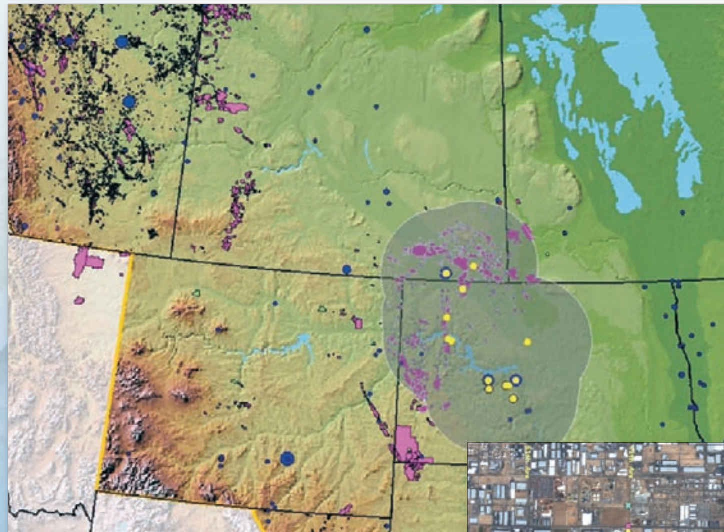
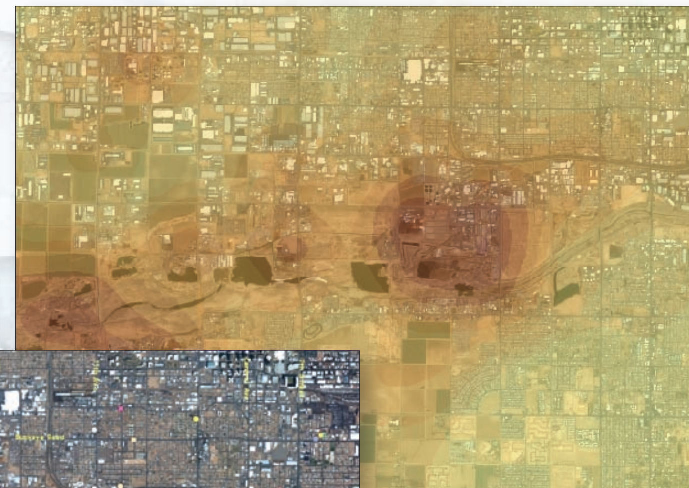
GIS Best Practices

GIS for Air Quality





December 2007

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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 the Conservation of Air Quality

Air quality is important to our health and environment, but sources of contamination are often difficult to monitor. GIS technology manages statistical and spatial data to provide a tool that shows the relationship between poor air quality and occurrences of deficient human and environmental health. In this way, a GIS aids in monitoring pollutant emissions.

The EPA implemented the Clean Air Act to protect our environment from the harmful effects of pollution. A GIS can be used to track the EPA regulated pollutant emissions by delineating the effects of ozone, smog, dust, and other harmful airborne pollutants on plant and human life. By monitoring those relationships, a GIS becomes a tool conservationists can use to ensure that no further pollution occurs. GIS technology allows us to locate where pollutants are coming from and monitor those areas for change to conserve the quality of our air.

Carbon Dioxide Sequestration Communications Supported by GIS

A Study of the Great Plains of North America

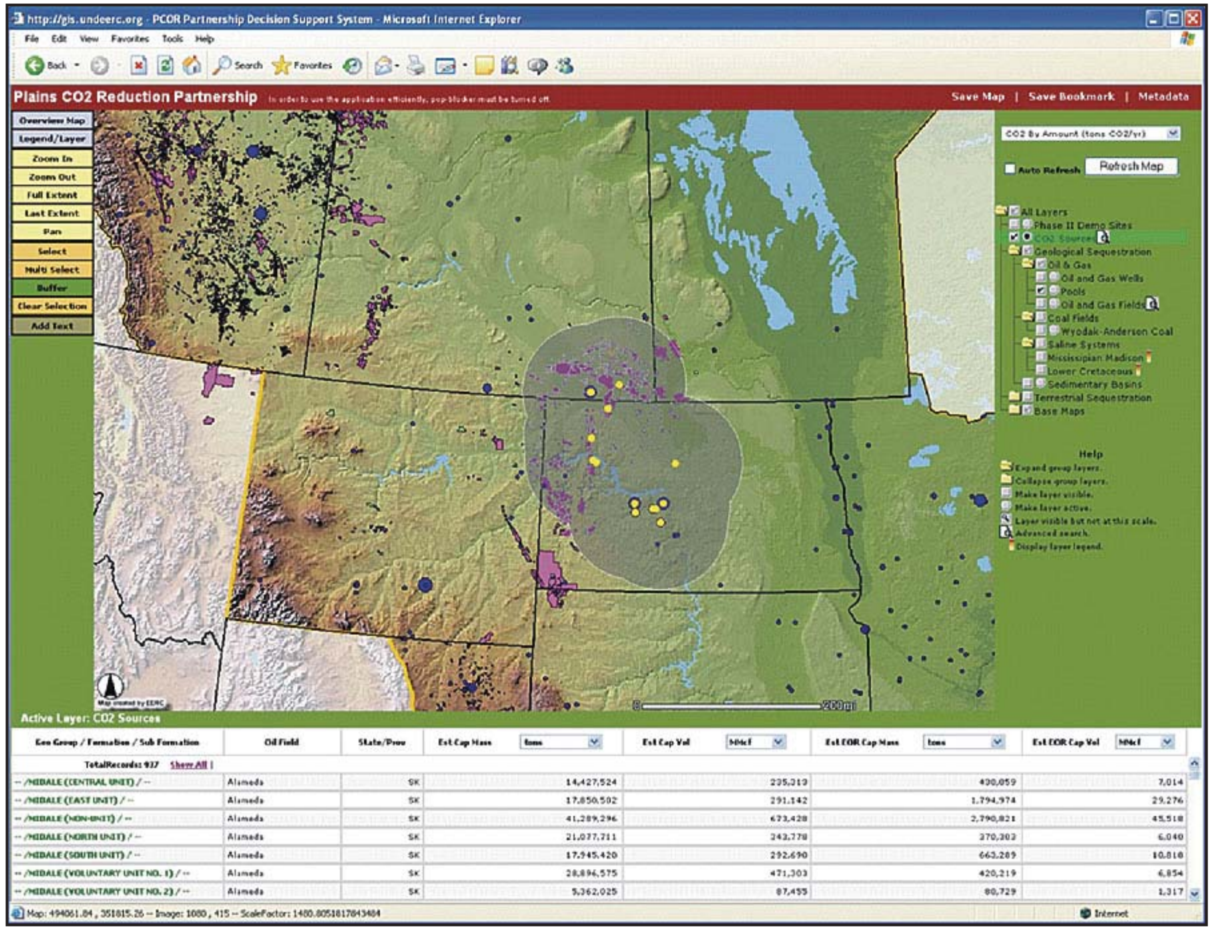
Affordable energy not only fuels our vehicles and electrical plants, it also fuels our economy and our quality of life. However, most of today's energy technologies release carbon dioxide (CO_2) into the environment, and there is growing concern that CO_2 in the atmosphere might affect global climate and weather.

The University of North Dakota Energy & Environmental Research Center (EERC) is leading an international team to develop opportunities for CO_2 sequestration in the Great Plains of North America. This team, the Plains CO_2 Reduction (PCOR) Partnership, is one of seven regional partnerships established by the U.S. Department of Energy/National Energy Technology Laboratory (DOE/NETL) to determine the most suitable technologies, regulations, and infrastructure needs for carbon capture, storage, and sequestration in different areas of the United States and Canada.

Through the collaboration of more than 50 government, industry, and environmental groups, the PCOR Partnership is currently characterizing CO_2 sources and sequestration opportunities in nine U.S. states and three Canadian provinces—in all, nearly 1.4 million square miles.

A major component of this characterization is creating an inventory of large stationary sources of CO_2, identifying and mapping geologic and terrestrial targets, or sinks, for CO_2 sequestration across the PCOR Partnership region. Knowledge of the character and spatial relationships of sources, sinks, and regional infrastructure is basic to developing and assessing approaches to economical CO_2 sequestration.

The most efficient way to communicate this information to the partners has been through a GIS-enabled Web site built with ArcIMS software, which was selected following competitive evaluation because of its versatility in both the GIS and Web environments. This site is a major component of a larger Web-based decision support system (DSS) that provides the research team with a single point of access to a wide variety of research data for the evaluation of sequestration data and the development of potential scenarios. This password-protected Web-based platform contains the tools and capabilities designed to deliver functional and dynamic access to data acquired through the project. The data is housed in a relational database and accessed through a map-based portion of the Web site. More traditional Web pages provide access to relatively static data, such as links to reports, CO_2-related Web sites, terrestrial maps, and snapshots of regional data.



The Plains CO_2 Reduction Partnership Decision Support System showing the selection of oil pools (potential CO_2 sequestration sites) within 75 miles of selected CO_2 sources.

The Web-based GIS portion of DSS is designed using ArcIMS, which provides a scalable framework for GIS Web publishing.

GIS technology enhances the users' understanding of regional opportunities by allowing them to visualize the spatially distributed nature of the data. DSS contains several analysis methods that allow members of the research teams to browse, query, analyze, and download data regarding CO_2 generation and sequestration in the PCOR Partnership region. Researchers can use the GIS to

- Examine attributes of individual features or groups of features and their spatial relationships to other features.
- Query the underlying data to analyze the region and export selected data for manipulation in other software.
- Explore the nature of the data through thematic maps.

In addition to enabling the user to directly select features on the map, the site allows the user to employ advanced selection methods. The attribute query option is a powerful tool for finding and examining features and data based on specific data attributes. An alternative feature selection process allows for sink/source proximity analysis that can be employed through a spatial query. This approach uses the buffer tool to identify features that are located within a user-specified distance of currently selected features.

The Web-based GIS interface of DSS contains several themes of georeferenced data that are considered crucial for the PCOR Partnership project. This data includes detailed source and sink characterization information that has been collected or generated by the research team. Several base layers and associated characteristics are also available, including political boundaries, cities, regional geology, road and rail transportation, shaded relief, and land use.

The majority of the source characterization data was gleaned from public data sources, such as U.S. Environmental Protection Agency (EPA) Web sites. The database currently contains information regarding all stationary CO_2 sources in the PCOR Partnership region. Stationary sources include heat and power generation (utility, industrial, institutional, and municipal) and industrial facilities representing the food, fuels, chemicals, minerals, metals, paper/wood, manufacturing, and waste-processing industries.

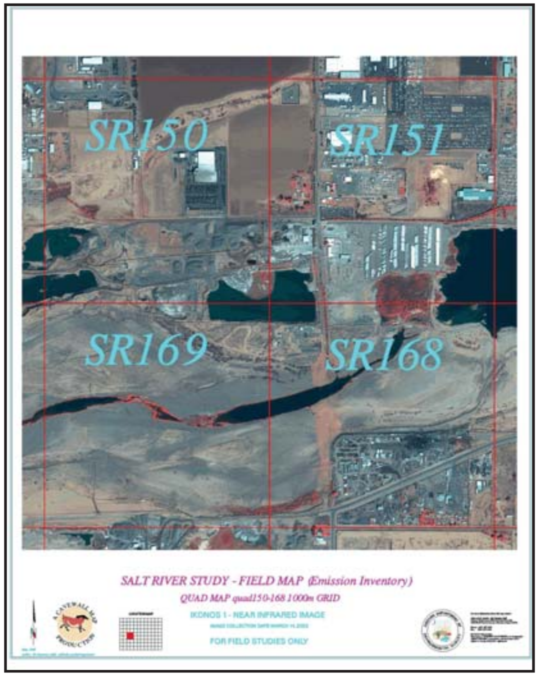
Largely, CO_2 emissions were estimated using fuel utilization data or unit production emission factors (e.g., tons CO_2/gallon ethanol). Sulfur and nitrous oxide emission data was included wherever available. Emission data is initially displayed in tons CO_2/year (mass) and million cubic feet (mmcf) CO_2/year (volume); however, the ArcIMS interface has a converter for users to select different units, such as tons CO_2/year or mmcf CO_2/day.

The petroleum-related data (well and field locations along with associated management, production, and stratigraphic data) was provided by state agencies or gleaned from publications; however, the level, or detail, of available data was not always consistent from state to state. The database currently contains information on more than 400,000 wells with various attributes, including operator name, well name, total depth, well type, and well status. Reservoir characteristic data was obtained by researching state agency case files for fields with a cumulative oil production greater than 800,000 barrels. This data pertains to reservoir characteristics that are necessary to perform detailed field studies with respect to CO_2 sequestration, including porosity, permeability, reservoir thickness, surface area, original oil in place (OOIP), cumulative production data, and water and oil characteristics.

(Reprinted from the Winter 2006/2007 issue of *ArcNews* magazine)

Dust Mapping in Arizona Uses GIS and Satellite Imagery

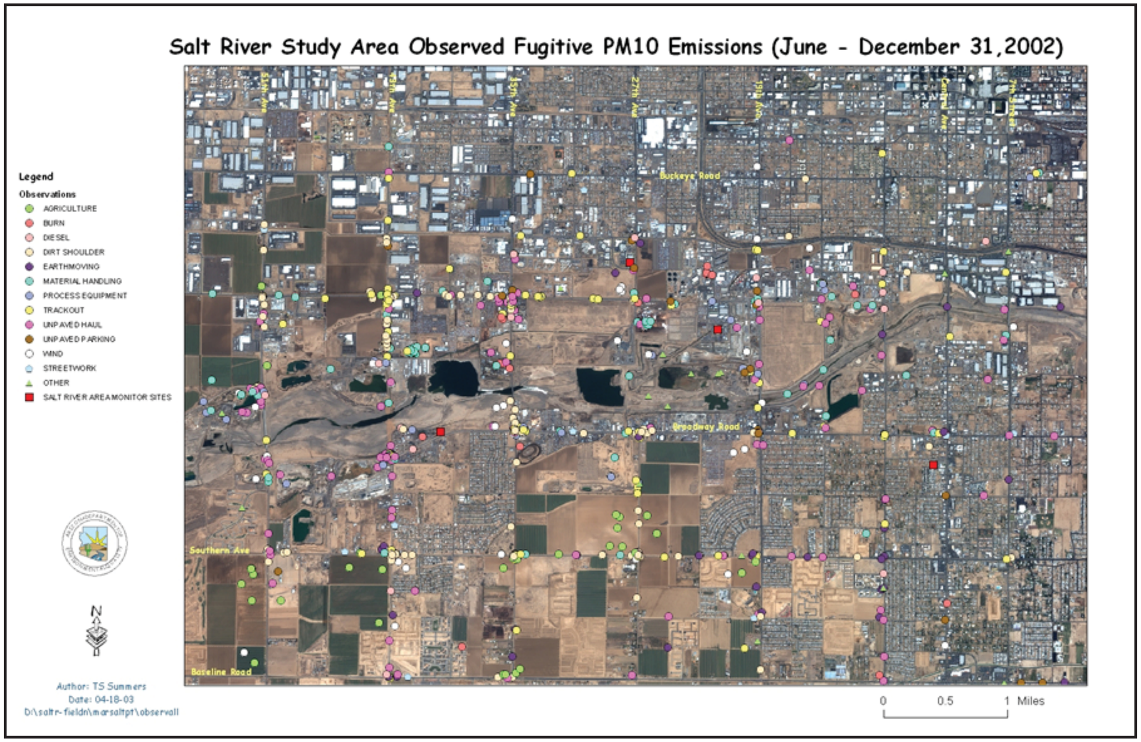
GIS is used to process and interpret satellite imagery and to produce valuable tools for environmental dust analysis. Increased resolution from improved satellite imagery, combined with GIS technological advancements, provides environmental managers with incredible geospatial research images. On-the-ground field crews, using mobile GIS technology, capture additional geographic data and perform inspections, dust inventories, and site verification, all of which are uploaded to the geospatial database. Maps produced with GIS can alert scientists to notify people residing in areas where hazardous dust is approaching to take precautions. Decision makers use environmental dust maps to implement dust control measures, such as vegetative covering, barrier methods, irrigation, and street sweepers.



Indexed data sets are shown on a grid layer useful for modeling dust source information.

Dust is always in the air. Its quality and density depends on various factors, such as source, climate, and the direction and velocity of the wind. Today's high-resolution satellite imagery makes it easier than ever to identify dust source areas. Dust source points and the types of dust they generate can be displayed on a GIS map. GIS modeling and statistical analysis are useful for predicting the effects wind and climate have on moving dust into the air and how long certain particle types remain suspended in the air. Types of dust and dust toxicity levels can be color coded and depicted on a map.

Arizona's desert environment creates dusty conditions. The Arizona Department of Environmental Quality (ADEQ) needed to find an accurate way to collect field geospatial data for air quality emission inventories. Tom Summers, ADEQ GIS project manager, began developing geospatial emission data in 1999. Since then, he has noted a marked improvement in satellite imagery and GIS technology that has made his data more accurate and more useful.



Dust source points are categorized and incorporate fugitive PM10 emission data.

"Being able to put two components together to build a system to manage the environment," says Summers, "is the most powerful tool that we have to this day and for the next 10 years in the future."

In the past, field-workers collected source-point data and wrote on paper maps to note what they found in the field. These on-site observations were later compiled in a spreadsheet for policy makers. In the early 1990s, Summers began to use satellite imagery with 30-meter Landsat or 25-meter SPOT data, which included 10-meter panchromatic black-and-white photos. The resolution was good for performing regional studies but not adequate for specific area studies. Aerial photos were useful but expensive. Summers explains, "If I was doing a study to analyze urban development and the residual environmental effects, the cost of aerial photography was too expensive. New images from IKONOS and more recently QuickBird satellites have made the satellite imagery more affordable and more useful."

Today's satellite imagery is much improved. For example, QuickBird satellite imagery delivers resolution as high as 2.44 meters (8 feet) multispectral at nadir. At this level, the reader can easily see dirt roads, fields, and human activities that create dust particle matter that is less than 10 micrometers in size. Summers first used the high-resolution satellite imagery along the Arizona-Mexico border in Douglass, Arizona, and Agua Prieta, Mexico, the fastest growing city in Mexico. He found satellite data had many more advantages than aerial photography. It is less expensive, is clearer, delivers images over borders without legal barriers that airplane imagery faces, and is easily put into the same projection system used by the state of Arizona.

Next, the data is indexed. Summers describes his indexing method, "First I grid the images, which has two benefits: (1) The procedure gives me an index, so people in the field can be on the same page with the people who are taking the information off the images in the office. (2) Grid maps can be used in a model."

Modeling uses a specific grid size and takes information off that grid and relates it to a number of certain types of activities. Originally these maps were printed on paper; now they are input onto field-workers' Tablet PCs. Once a coverage is digitized, the user engages GIS to attribute the coverage according to land use activities. The modeling grid is placed on top of the coverage, and the two are merged. With ArcGIS Desktop (ArcInfo and ArcEditor), instead of having one coverage of various land uses, you can set the grid up to show the percentage of land area within a grid that has a certain activity.

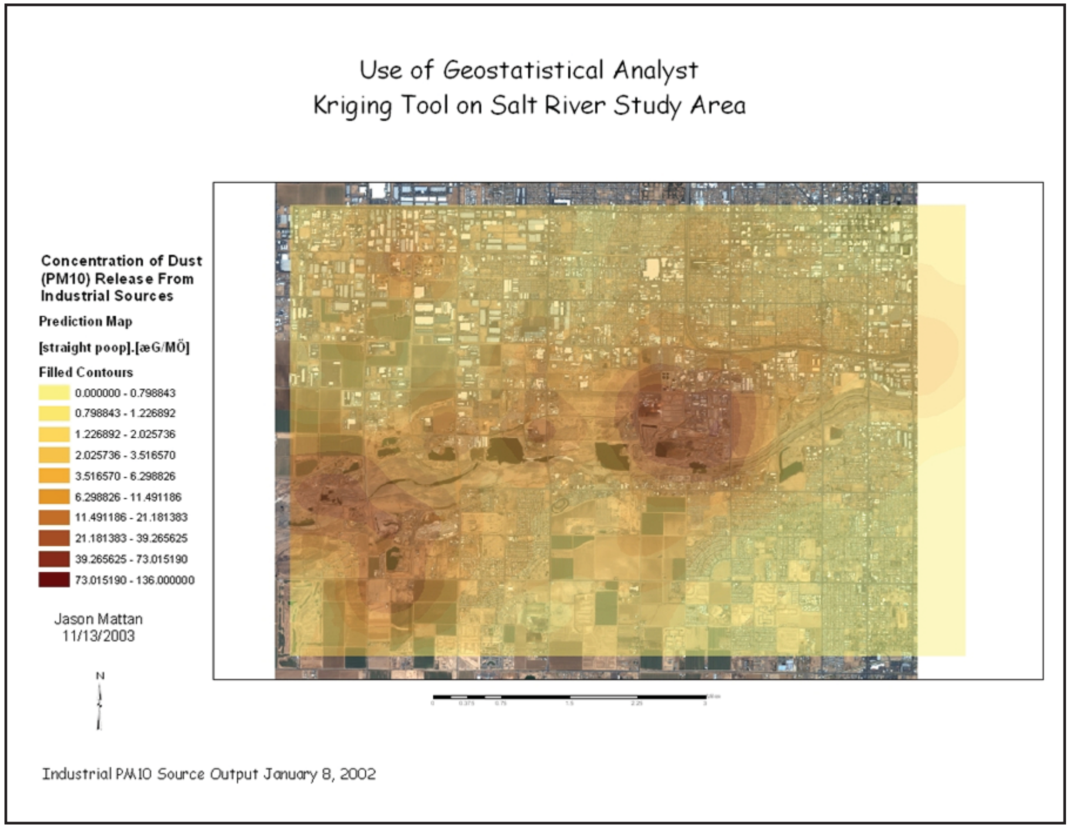
Edited data is then entered into ArcGIS Desktop, which is used for digitizing polygons on the space imagery. Creating the polygons and color coding them according to land use and land characteristics make the maps very useful in the field. The Environmental Protection Agency (EPA) has inventory codes for specific land uses. Using these numbers, we code, for example, agricultural lands as 42 in the inventory database. ArcGIS Desktop uses the database table to create a polygon that shows that code's particular land use. EPA has scientific models for evaluating certain types of land use and emission factors. These factors are added to the ADEQ model and run.

Tablet PC users can do editing in the field.

Prior to mobile GIS, field-workers marked up paper maps and brought them back into the office where the information was digitized into ArcInfo. This transfer of data from hand notes to the computer was the longest step in the process. Tablet PCs are reducing this process greatly. Rather than printing a map, the digitized coverage is downloaded to the Tablet PC and the field-worker uses ArcEditor to enter field data. All the shapefiles created for a project are on the field computer. ArcEditor allows the field-worker to digitize on the shapefile. "We first create the coverages in ArcGIS Desktop," explains Summers. "Next, we set up the basemap using the imagery and boundaries of the study area, and we add the grid map and download it to the Tablet PC. The field people take the Tablet PCs into the field and digitize the files."

A GIS-enabled Tablet PC enables the user to interact with the map using a digital pen. Field-workers can draw a circle on the map for zooming. Digital ink functionality allows the user to quickly navigate and mark up a GIS map. Field-workers are adding to the database and attributing while actually in the field. In addition, they have the ability to add GPS information as a cross-reference of the satellite imagery, thereby enhancing data quality assurance. By adding graphical user interfaces (GUI) on the Tablet PC applications, the task is made easier for field-workers and training time is reduced. For example, with a button-activated GUI menu, the user simply pushes a button and the map sets up. The worker uses the digital pen to enter polygon information for a redline layer. With the push of another button, the attribute list opens. The attributes are immediately available for selection. The captured data, whether from the GPS, inventory list, or digital notation, is entered into a data file or shapefile. The worker brings the mobile computer back to the office and uploads the information into the main system's geodatabase.

In the office, the GIS manager reviews and edits the shapefile for dangles or extraneous polygon information for the coverage. Once the coverage is cleaned up and ready, the grid is once again laid on top and the field information is added to the model. GIS-enabled Tablet PCs speed up the database editing process and provide more accurate data for modeling. The high-quality geospatial database can be accessed for complex manipulation; for example, data can be further explored using the ArcGIS Geostatistical Analyst extension to identify anomalies, perform prediction, evaluate uncertainty, and create surfaces.



The Arizona Department of Environmental Quality runs its data through ArcGIS Geostatistical Analyst to show how types of dust pollutants are created at the source point level and dust levels of intensity.

After years of experience monitoring the environment using geospatial technology, Summers has learned some lessons. "Most people are overly concerned about costs, but they cannot afford to be. It is going to cost them more in the long run if they scrimp in the short run. Another key is to carefully listen to other people's insights because everyone on the team has experiences they can add to the project. A cooperative environment makes the project easier and more exciting, and the outcome is a better product."

Summers says, "Effective environmental practice considers the whole spectrum of the environment. ArcGIS technology offers a wide variety of analysis tools to meet the needs of many people. It prepares information for managers, politicians, and others to help them make better decisions about the environment."

(Reprinted from the Winter 2004/2005 issue of *ArcNews* magazine)

Colorado's North Front Range Metropolitan Planning Organization Makes Ride Sharing Easier with GIS

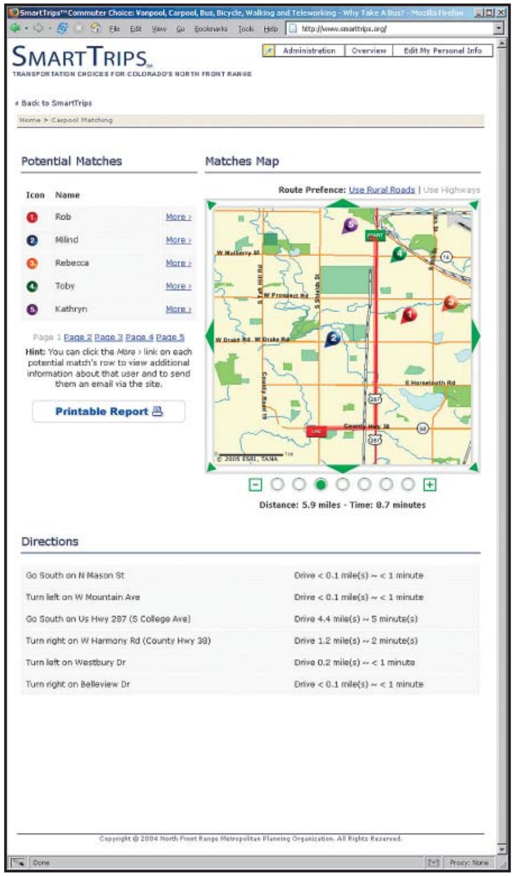
Colorado's North Front Range Metropolitan Planning Organization (NFRMPO) is a designated transportation and air quality planning organization. NFRMPO's objective is to provide long-range transportation planning, including information, tools, and public input, for improving the regional transportation system's performance. NFRMPO engages in cooperative decision making through working relationships and financial partnerships among the member governments, the Colorado Air Quality Control Commission, Colorado Transportation Commission, Federal Highway Administration, and Federal Transit Administration.

NFRMPO comprises 13 member governments in Colorado (Berthoud, Evans, Fort Collins, Garden City, Greeley, Johnstown, Larimer County, LaSalle, Loveland, Milliken, Timnath, Weld County, and Windsor), covering 40 square miles and working on behalf of almost 360,000 northern Colorado residents.

In 1993, NFRMPO created a program called SmartTrips to provide information about alternative and cost-saving transportation choices to the residents of northern Colorado, including carpooling, vanpooling, bicycling, walking, taking the bus, and teleworking.

One of SmartTrips' premier services is an online carpool matching program. Carpooling allows the flexibility of driving alone on days when errands need to be run or someone needs to work late, while still providing the benefits of carpooling the other days.

The program works by matching prospective riders from a database of more than 1,500 carpoolers who have similar destinations and schedules. Available through the SmartTrips Web site (www.smarttrips.org), the program offers commuters a cost-saving alternative to the daily commute and is available at no charge.



SmartTrips Web-based ride-sharing system allows users to instantly identify potential matches and view their proximity on a map.

Ecology and Environment, Inc. (E&E), an ESRI Business Partner and a Lancaster, New York, firm, won a contract to update the SmartTrips electronic ride-share program in fall 2004. NFRMPO wanted a more interactive Web-based ride-share system with online map content that would allow users the ability to search for their own matches. Along with sister firm Walsh Environmental, E&E implemented ESRI's ArcWeb Services Internet mapping technology into the ride-share application for ease of use by commuters.

The updated SmartTrips program helps residents in three of the Colorado communities served by NFRMPO—Fort Collins, Greeley, and Loveland—travel as often as possible without using a car. SmartTrips provides resources, information, and incentives to help users accomplish this goal, decreasing road stress, saving users money, and decreasing traffic for everyone in the area.

The mission of the Web site is to provide information to help citizens choose smart transportation options.

ArcWeb Services provide the updated maps and geocoding service for those looking to share rides. By using www.smarttrips.org and joining an online rewards club, MySmartTrips, users have online, instantaneous carpool matching, tracking of the money saved by not driving alone, a tally of the calories they've burned by walking or bicycling, and automatic e-mail notices of upcoming events.

Users control the personal information that is shown to other carpoolers. Once a profile is created, possible carpoolers and their e-mail addresses are displayed and they can then be contacted by e-mail.

The SmartTrips site also includes tools to help locate other transportation options, such as bus, vans, bike routes, and park-n-ride lots. SmartTrips is applicable to daily commuters, as well as to those who are making longer, less frequent trips, such as to vacation destinations. All of this is accomplished while maintaining a user's confidentiality.

NFRMPO was pleased with the results of using ArcWeb Services, as it saw a 400 percent increase in SmartTrips' usage in the first quarter of 2005 compared to the same period the year before.

"The North Front Range Metropolitan Planning Organization had a unique request to build a carpool matching service that needed to be very customer friendly," says Margie Joy of the organization. "It also needed to have administrative tools that could be accessed from multiple network systems. This system is just what our community needed."

After successfully integrating GIS into SmartTrips, E&E saw more opportunities for ride-sharing applications beyond NFRMPO. The result was GreenRide (www.greenride.com), which helps reduce single-vehicle passenger trips by searching for carpool partners or other transportation methods that are convenient for users in meeting their commuting preferences. GreenRide also uses ArcWeb Services to geocode both the carpooler's home and destination locations.

A sophisticated algorithm combines location coordinates with user preferences to produce potential carpooling matches. Interactive maps allow users to visualize their route options and create a scenario that fits their needs.

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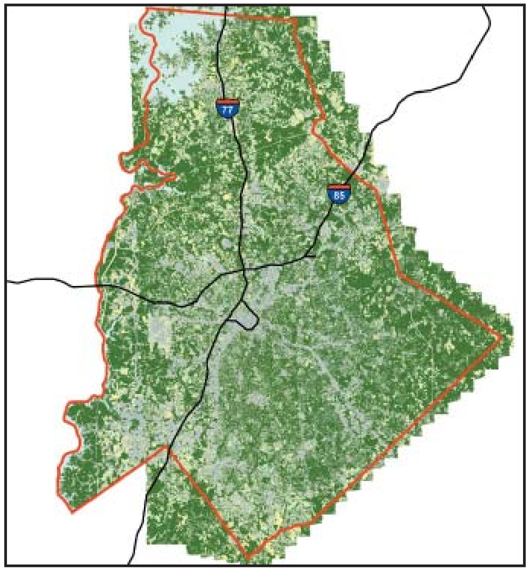
The Charlotte, North Carolina, Urban Area Now Has a "Green Theme"

By Gary Moll, American Forests

The Charlotte, North Carolina, metropolitan area is among the top 10 fastest growing metropolitan areas in the nation, and Mecklenburg County, which houses the city, has seen a 72 percent growth in population since 1980 according to the U.S. Census Bureau. With such a boom in population, some loss in natural vegetation is inevitable. However, the rate of urbanization and tree loss in Mecklenburg County surpasses even that of population growth. Between 1984 and 2001, the county saw a 127 percent increase in areas covered by impervious surfaces. Without a balance between impervious and tree-covered land, the county's citizens will face costly and unhealthy environmental consequences.



Mecklenburg County's different land covers are highlighted. Dark green represents tree cover, light green represents grass and open space, and gray designates impervious surfaces.

Consider the lessons learned about growth and development of the I-485 Outerbelt highway. An analysis of Landsat imagery from 1984 and 2001 shows a 42 percent loss in tree cover and a 194 percent increase in impervious surfaces. This change in land cover was measured using a two-mile buffer around a 12-mile section of the highway. Measuring the impact of this one section of the beltway provides community leaders with a feel for the future impact of the planned roadway. The environmental impact of the entire Outerbelt will be huge. If the highway development project continues its growth, it will push away from the city center in a sprawl pattern. The challenge to the community is how to manage growth while maintaining efficient use of its land and a robust green infrastructure. Finding a solution to this problem is the focus of this article.

Charlotte's mayor, Patrick McCrory, says, "Our trees are the city's signature." And, like John Hancock's on the U.S. Declaration of Independence, this signature is easy to read. The mayor challenged Charlotte's Tree Commission to establish a new tree ordinance for the city that would ensure the signature status of the trees in the future.

Rick Roti, citizen chairman of the Tree Commission, says, "It was a challenge that kept us busy for a year, but we now have a good ordinance."

The mayor's tree signature also appears on the regional air quality improvement effort, called Sustainable Environment for Quality of Life, centered around Charlotte's urban area and organized by the Centralina Council of Governments. The city's air quality is dangerously close to the Environmental Protection Agency's "nonattainment" designation. If the air quality deteriorates, giving the area a nonattainment status, the region stands to lose $6 billion in federal highway funding, not to mention risking the health of the area's residents. To improve the air, the area has agreed on a checklist of a dozen actions, and improving the tree canopy is one of them.

Charlotte's arboreal signature has become part of the city management fabric thanks to the power of GIS technology. A green data layer (tree theme) became part of the city's central database about a year ago. As a result of this technical action, managers throughout the city have access to the tree theme in the GIS and can include tree cover concerns in daily infrastructure management efforts. The city of Charlotte and Mecklenburg County have the technical expertise to use the green data layer effectively, but it is the Land Development Division of the Engineering Department in the city of Charlotte that has utilized the data most intensively. The department has joined the rest of city government in using the ArcGIS platform.

Laura Brewer, senior urban forestry specialist, and Nick Roberts, systems analyst with the Engineering Department, have long-time familiarity with ArcView software. Following a period of competitive analysis, they chose the CITYgreen extension from ESRI Business Partner American Forests to evaluate the impact of development proposals received by the city on current and future tree cover.

For the large-scale analysis this means using ArcGIS Desktop software and CITYgreen to create a baseline of current conditions by combining land cover and land use data. The current condition is then fed into a land use projection model to establish a metric for future land cover. The future land cover includes specific measures for tree cover that are then compared to the requirements set forth in the tree ordinance. This analysis provides direction to the public policy makers so they can determine the effectiveness of the development code at controlling tree loss.

"This is accomplished by modeling the development proposals using GIS technology," says Roberts. "We use the green data layer produced by American Forests for the city's GIS, along with other growth and development data, to conduct our analysis."

The small-scale analysis allows the Land Development Division to evaluate the impact of all new development or rezoning on the tree cover and make immediate adjustments in development in keeping with the tree cover goals of the tree ordinance.

The efforts by the city of Charlotte to incorporate a green data layer into its central database and establish application of the data in the Engineering and Property Management section of the city government is a groundbreaking action that should be considered by every urban government.

(Reprinted from the Summer 2003 issue of *ArcNews* magazine)

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. ESRI applications, running on more than one million desktops and thousands of Web and enterprise servers, provide the backbone for the world's mapping and spatial analysis. ESRI is the only vendor that provides complete technical solutions for desktop, mobile, server, and Internet platforms. Visit us at www.esri.com.

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