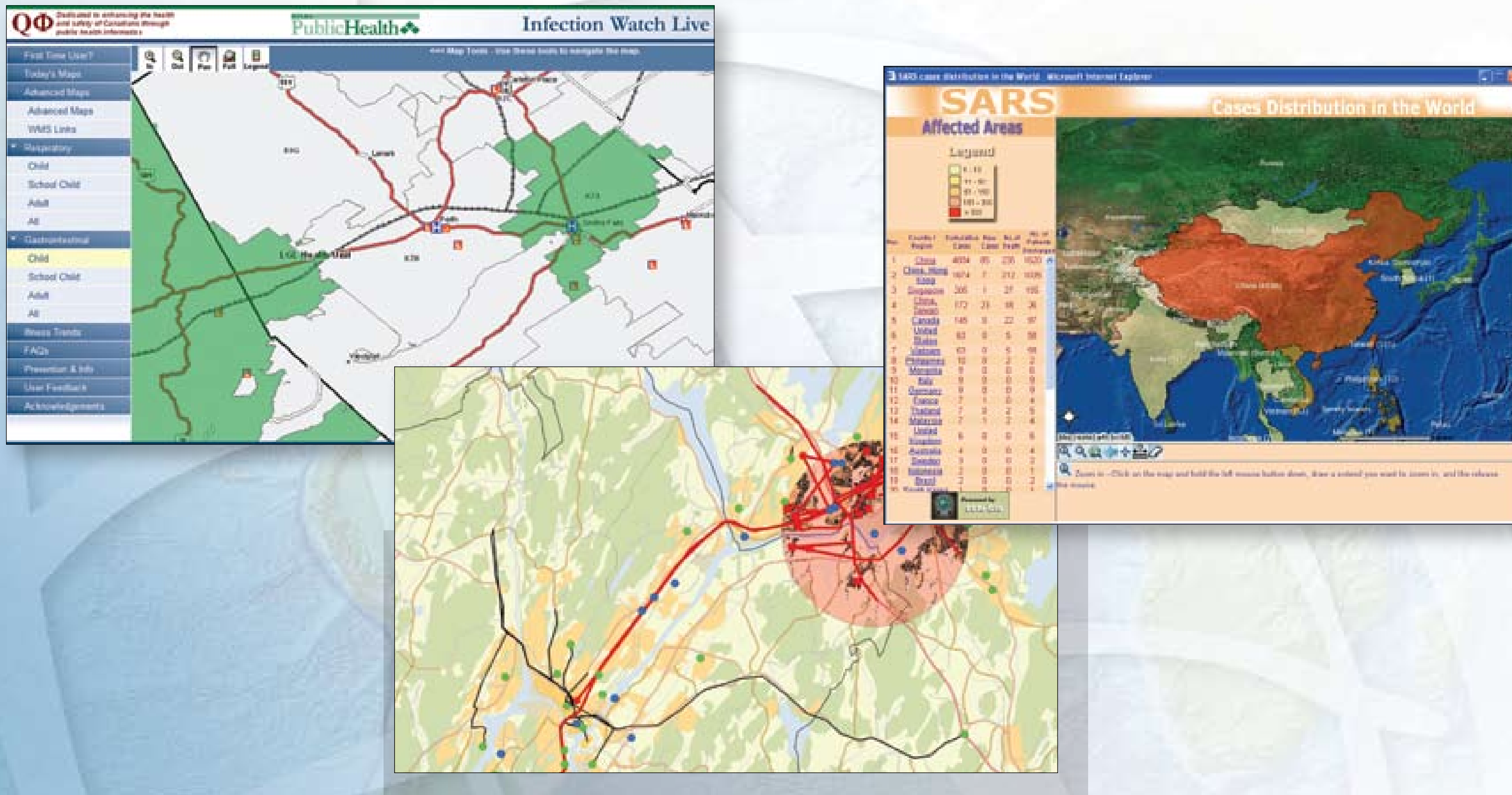
GIS Best Practices

Early Detection and Response to Infectious Disease



August 2009

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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 Early Detection and Response to Infectious Disease

Successful understanding and response to infectious disease outbreaks depend greatly on the ability to consider the surrounding context. Disease spreads geographically, and interventions occur in relation to human, institutional, climatic, and other kinds of landscapes. Because GIS technology relates many kinds of data to geographic location, it excels in tracking not only disease spread but also laboratory specimen and medical supply whereabouts, hospital bed availability, testing facility proximity, vulnerable population locations, and medical personnel distribution. Built-in GIS analysis tools provide effective early warning systems and preparedness programs that generate meaningful information that public health officials need to make effective decisions—at the community, national, and global levels.

During an outbreak, GIS provides tools that speed the collection of accurate field data. Complex statistical and other analyses applied with GIS technology provide relevant information to support sound decisions. GIS analysis can, for example, locate a potential disease hot spot and calculate a nearby hospital's ability to handle the expected increase in service demand if an outbreak should occur.

Public health emergencies are not of short duration. Effects of a disease outbreak (or an environmental disaster such as a chemical spill) have the potential for long-term impacts on the health and well-being of a community. Public health organizations rely on GIS analysis tools to assess data collected in the process of monitoring long-term health effects.

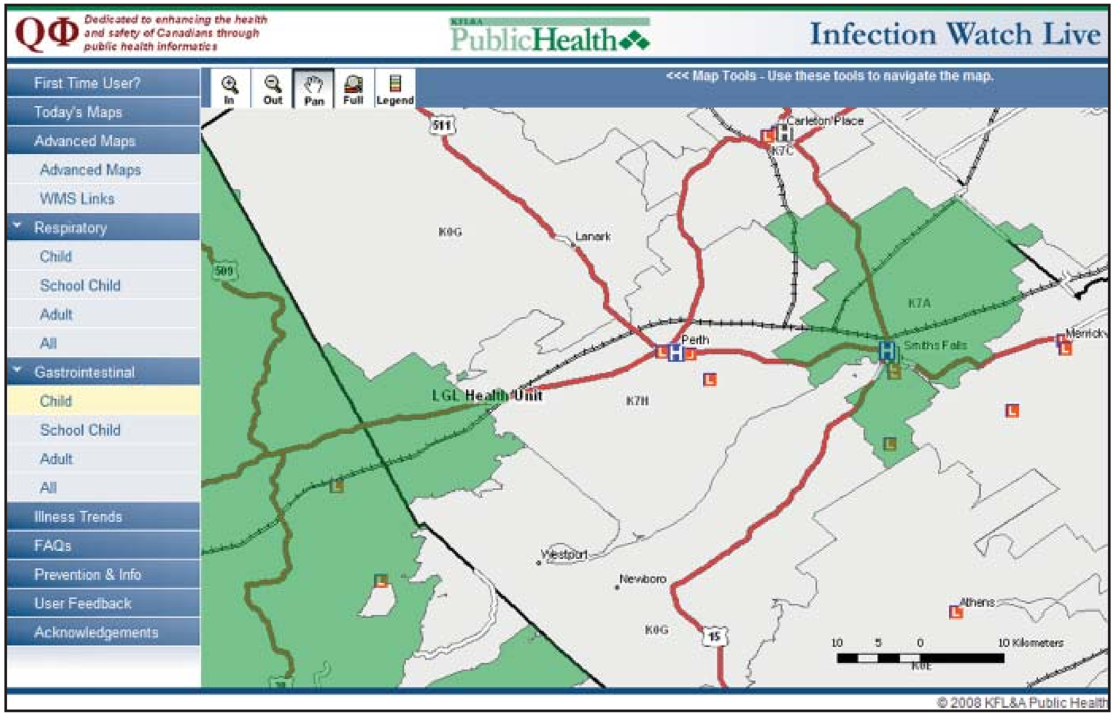
Health professionals use geospatial technology to

- Discover geographic origins of symptomatic populations.
- Identify specific locations of vulnerable at-risk populations.
- Identify congregate groups targeted for preventive measures.
- Create maps to help organizations establish field clinics and locate medical supplies.
- Provide information relevant for community leadership planning and response.

GIS Application for Early Detection Tracks Hospital-Reported Symptoms

Online, Interactive Maps Keep Community Informed

Health services groups in Ontario, Canada, are working with geographic information system (GIS) consultants to make real-time emergency room information available online as a way to inform community health providers, community members, and stakeholders. The application, based on ESRI's ArcGIS Server technology, generates summary maps of real-time respiratory and gastrointestinal data reported in hospital emergency rooms. Online access to these maps gives community stakeholders an at-a-glance picture of where to expect spikes in these illnesses.



A new Web application, Infection Watch Live, uses geography to inform an Ontario, Canada, community with current data on respiratory and gastrointestinal illnesses reported from nine area hospitals.

"The key element of this project is enhanced communication and collaboration between the acute care sector, public health, and the community at large to protect the public and prevent illness," says Dr. Kieran Michael Moore, project director at Queen's University Public Health Informatics (QPHI). The maps serve to inform decisions made by public health workers as well as family physicians, community care access centers, long-term care facilities, school and child care center administrators, and the general public. Institutions and schools can better understand and plan for absenteeism, and visitors to the site can also find related disease prevention and treatment information.

ESRI business partner Infonaut Inc. and the Sault Ste. Marie Innovation Centre developed the application in collaboration with Kingston, Frontenac, Lennox and Addington (KFL&A) Public Health; QPHI; and ESRI Canada Limited. GeoConnections, a Canadian government program that promotes geospatial initiatives, awarded sponsorship to develop the application.

"It's a great way to disseminate data," says Infonaut chief operating officer Matt McPherson. "You can see where a disease is active by a partial postal code [first three digits]. You can identify neighborhoods, towns, and municipalities and zoom in to identify different features of the community—schools, hospitals, day care, universities—in relation to reported hospital activity."

The KFL&A area is a public health region that covers some 180,000 residents in the municipal and county areas surrounding the city of Kingston—where Lake Ontario meets the St. Lawrence River—north through Frontenac County and Lennox and Addington County including rural towns and villages such as Napanee, Cloyne, and Sharbot Lake. From the start, project objectives were to contribute to informing the community, understanding and limiting disease spread, reducing mortality and morbidity among at-risk populations, and reducing impacts on hospital emergency departments. Presentation of the most up-to-date information in an easy-to-use interface would provide an easily understood early detection resource to the community.

"The establishment of a surveillance system using data from hospital emergency departments has been an invaluable tool for public health to identify infectious disease risks early," says Dr. Ian Gemmill, medical officer of health for KFL&A Public Health. He explains, "The identification of salmonella in bean sprouts is an excellent example. Extension through the Infection Watch Live Web site to our partners in the community and to the public will provide our whole community with real-time communicable disease activity information, allowing better health decisions."

For application development, two variables, respiratory and gastrointestinal complaints, were chosen because of their rapid transmission rates and high burden on community health services. The data source is real-time data collected from nine area hospitals by an electronic system adapted from the University of Pittsburgh's Real-Time Outbreak and Disease Surveillance (RODS) system, in use since 2004. Map data was obtained from the Canadian Geospatial Data Infrastructure, which provides online resources for digital maps and satellite images. A public health epidemiologist working on the project created an algorithm that models the seasonal patterns of respiratory and gastrointestinal infections in the community.

Site visitors get an overall picture of illness activity in the last 24 hours and see at a glance affected age groups and neighborhoods. Health authorities can access more detailed information through a secure connection.

Application maps present a generalized view of illness rates using three color zones—red, yellow, and green—to indicate high, elevated, and normal activity zones, respectively, in a display similar to at-a-glance air quality maps. This generalized view complies with health data privacy constraints by showing results for each syndrome by age groups (child, school child, and adult) and obscuring details about specific hospitals or patients. Results are displayed as a static snapshot of current activity or as interactive maps that group historical activity by syndrome and age group. The application can also make detailed data available to authorized health authorities, providers, and researchers through a secure Web mapping service.

An easy-to-use interface to the Infection Watch Live Web page allows visitors to customize maps of historic data on reported respiratory and gastrointestinal illnesses by date and region.

For more information, visit www.kflapublichealth.ca/.

(Reprinted from the Winter 2009 issue of *HealthyGIS* newsletter)

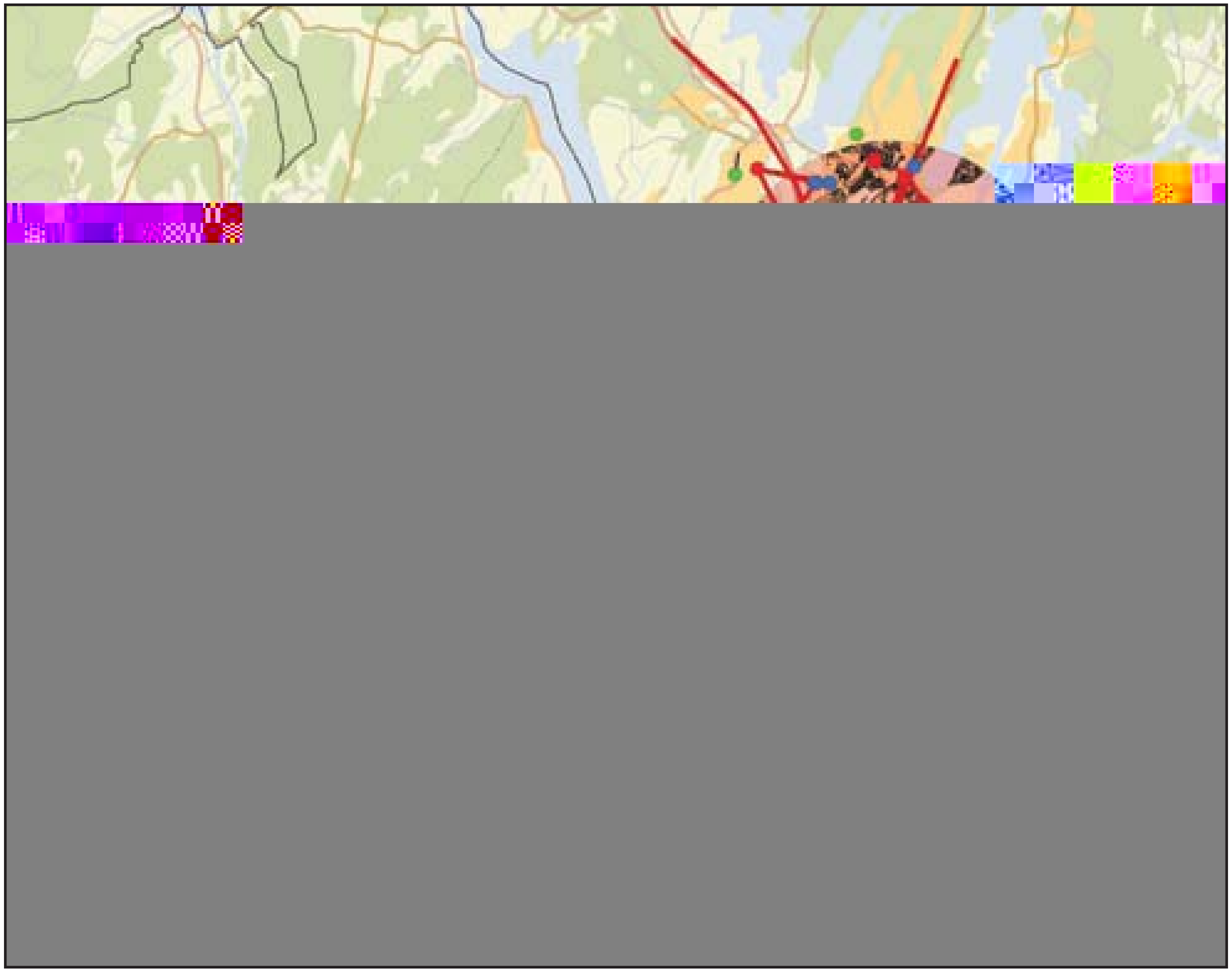
Spatial Analysis Gives Insight into Source of Legionnaires' Disease

By Arleen Engeset, Key Account Manager, Geodata AS, and Tore Jensen, Technical Specialist, Geodata AS

When a hospital in Norway alerted national health authorities about an outbreak of Legionnaires' disease, authorities reacted quickly to find the disease source. They used geographic information system (GIS) technology tools for data mapping, time series analysis, and visualization to analyze more than 50 cases of the infection. Although infected patients were scattered over a large area with no places visited in common, the tools provided by ESRI's ArcGIS software helped reveal a unique and unusual source of dispersal for the bacteria—a commercial air scrubber that released infected water droplets into the air. Geodata AS, ESRI's distributor in Norway, provided consulting services for mapping and finding the probable source of the outbreak based on GIS analysis.

Legionnaires' disease is a severe form of pneumonia caused by the *Legionella pneumophila* bacterium. The bacterium is most commonly transmitted by airborne droplets from contaminated water sources, such as cooling towers used in industrial systems, and is not readily transmitted from one person to another.

The Legionella epidemic took place in May 2005 in the neighboring municipalities of Fredrikstad and Sarpsborg. Together, the two cities form the fifth-largest urban area in Norway, with a total population of about 121,000. The outbreak was one of the biggest health crisis situations that Norwegian municipalities had dealt with in recent years.



An analysis of a three-kilometer buffer from the infected air scrubber (blue symbol in the middle) shows Legionella patients residing within the buffer (red boxes) and infected patients who live outside the buffer (red dots) and traveled through (red line) the buffer zone. Green dots show infected patients who live outside the buffer zone and have not traveled through it.

Time was of the essence to prevent more cases, but multiple and complex questions needed to be answered before the contaminated source could be identified. How many people were infected? Where did they live, travel, or work, and what were the most likely sources of infection? Control of the situation depended on the speed at which these and other questions could be answered, mapped, and analyzed.

Data collection methods conducted by health department personnel included interviews with infected patients and investigation of potential sources including 23 companies with cooling towers. Data collected for mapping in ArcGIS ArcInfo included

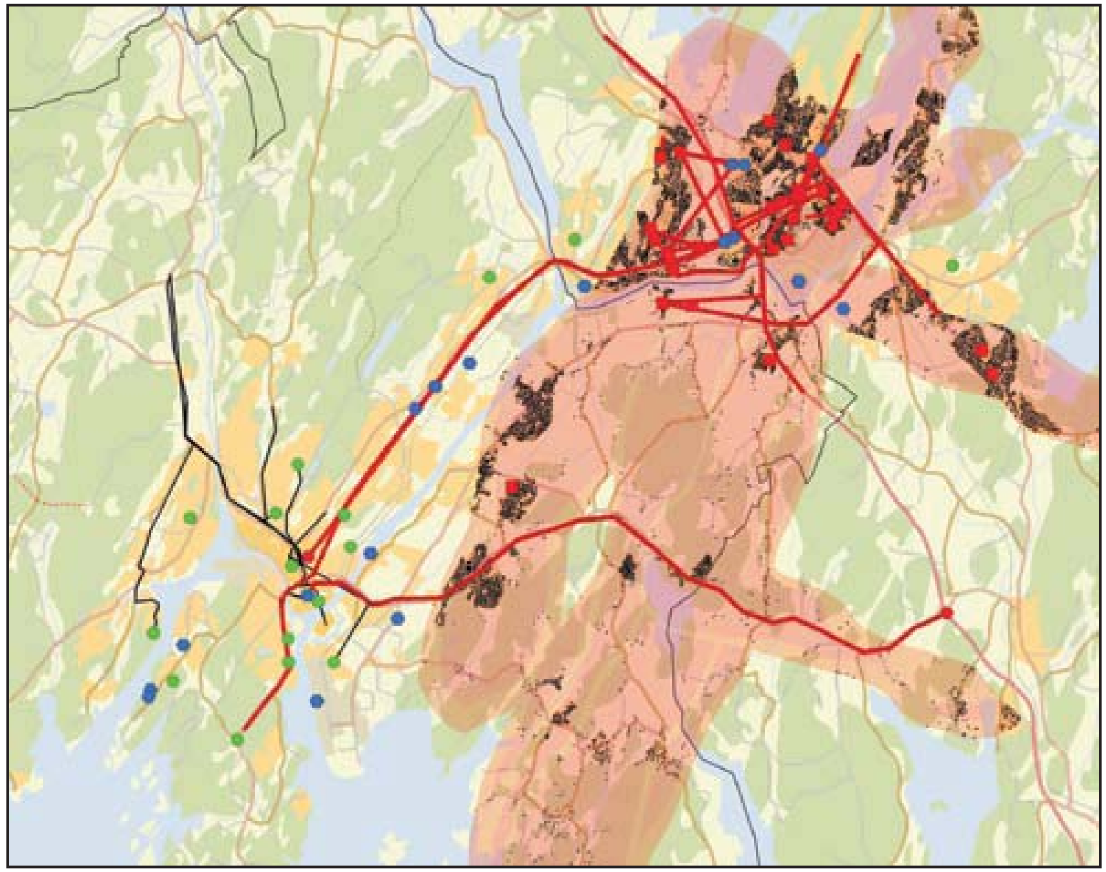
- Infected patients' places of residence
- Locations of cooling towers and other possible sources of infection
- Infected patients' movements over a 12-day period (280 routes)
- Wind and weather conditions

"GIS was helpful for this task, because digital mapping presents large data volumes in a simple and well-ordered manner, which is critical for the actual analysis itself," explains Øivind Werner-Johansen, director of health for the city and municipality of Sarpsborg. Other data included basemaps at a scale of 1:250,000 and demographic layers. The ArcGIS Tracking Analyst extension provided tools for analysis of time series data such as patient movement and wind patterns.

Next, case rates and risk ratios among people living within various radii of each potential source were calculated. The analysis was standard buffer/overlay analysis using buffer increments of 500 meters combined with the use of Tracking Analyst to show wind speed and direction. ModelBuilder contributed to this process by providing a template for running the buffer increments. The highest risk factor was found for those living within one kilometer of a commercial air scrubber, an industrial pollution control device that uses water to clean dust particles from the air. Inspection of the scrubber confirmed the presence of the infectious bacteria.

"The visualization that the digital map made possible is unique, and its contribution to the many decision-making processes we went through is beyond question," says Svein Rønsen, chief medical officer of the city and municipality of Fredrikstad. Both Werner-Johansen and Rønsen emphasize that effective municipal contingency plans and established joint procedures were critical for the efficient crisis management around the Legionella outbreak. The addition of GIS analysis helped solve the problem.

The two experienced disease fighters are pleased that the two municipalities now have GIS-based public-health and disease-control resources available. For small municipalities with few resources, Rønsen and Werner-Johansen recommend building a cooperative agreement among several local authorities to build GIS capabilities.



The footprint plume of contaminated air from the air scrubber was created based on hourly weather data. The result shows which cases are within the footprint (red boxes) and infected patients outside the footprint (red dots) who have traveled through it (red line). Green dots show infected patients who have not entered the footprint plume.

Successful use of GIS to resolve the Legionella outbreak also convinced Preben Aavitsland, departmental director, Division of Infectious Disease Control, Norwegian Institute of Public Health, of the benefits to be gained from GIS. Aavitsland describes the tool as being indispensable for reacting to similar situations in the future and advocates further strengthening of GIS expertise among the division's emergency preparedness team. Concludes Aavitsland, "Using GIS, we are able to quickly analyze large volumes of data, the overall picture becomes clear, and the results are easier to interpret."

For more information, visit www.geodata.no. A journal article on this project was published in the January 1, 2008, issue of *Clinical Infectious Diseases* with the title "An outbreak of legionnaires disease caused by long-distance spread from an industrial air scrubber in Sarpsborg, Norway," by authors K. Nygård, Ø. Werner-Johansen, S. Rønsen, D. A. Caugant, Ø. Simonsen, A. Kanestrøm, E. Ask, J. Ringstad, R. Ødegård, T. Jensen, T. Krogh, E. A. Høiby, E. Ragnhildstveit, I. S. Aaberge, and P. Aavitsland. An abstract of the article is available at www.pubmed.gov by searching for Nygard Werner-Johansen.

(Reprinted from the Summer 2008 issue of *HealthyGIS* newsletter)

GIS Empowers Emergency Response and Public Health Awareness

South Carolina Department of Health and Environmental Control

State-level public health agencies regularly deal with issues that require large amounts of data to be processed, integrated, analyzed, and distributed to many different end users. End users comprise a diverse internal and external group including concerned citizens, community organizations, health care workers and administrators, university researchers, and other state agencies. Within each group, technical capabilities and needs vary. With limited resources, these agencies need to determine the most appropriate way to make information available. Time and budget constraints, agency cooperation and collaboration, enterprise architecture, legacy processes, privacy concerns, and existing infrastructure are some of the issues. To facilitate most of this data processing, the South Carolina Department of Health and Environmental Control (SC DHEC) has turned to geographic information system (GIS) technology.

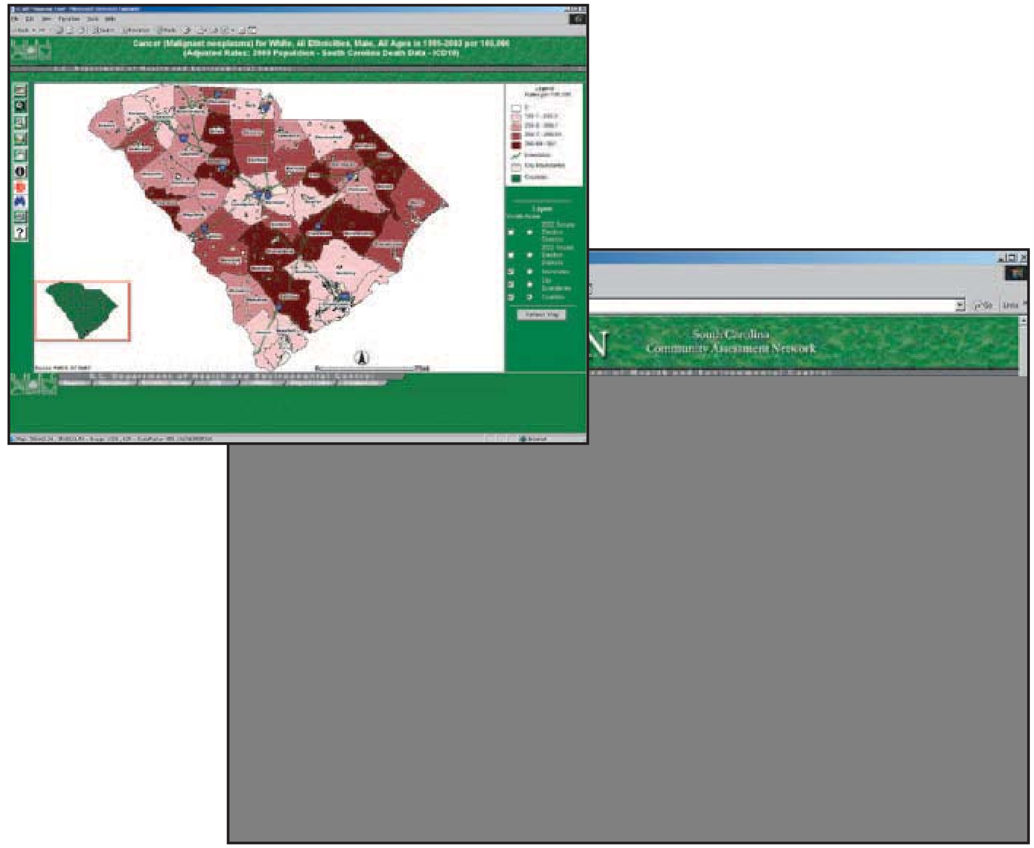
The Challenge

The Division of Biostatistics and Health GIS, a subset of the Public Health Statistics and Information Services (PHSIS) program within SC DHEC, knew it needed a way to serve its users' geographically based public health and emergency management information. With limited resources, the agency had to determine the most appropriate way to leverage this information. It needed to allow access in a way that accommodates its diverse audience while aiding the daily decision-making process in public health assessment and surveillance. Different levels of access to this information had to be available with ample security measures in place. In addition, since the data resided in various formats on multiple servers running different operating systems and relational database management systems, it all needed to be integrated and accessible to everyone. Once the data was integrated, it also needed to be current and well documented. Knowing these challenges, SC DHEC went looking for an innovative solution to serving the public necessary information.

The Solution

To address these issues, the division employed a diverse set of GIS technologies from ESRI, chosen because most state and city organizations in South Carolina used ESRI software as a standard.

SC DHEC adopted ArcSDE and Microsoft SQL Server for managing the statewide maps and data and ArcIMS and ArcIMS Route Server to serve information and provide driving directions and routing capabilities on the Internet. SC DHEC deployed the system on HP ProLiant rack-mounted servers to streamline integration and facilitate load-balancing requests.

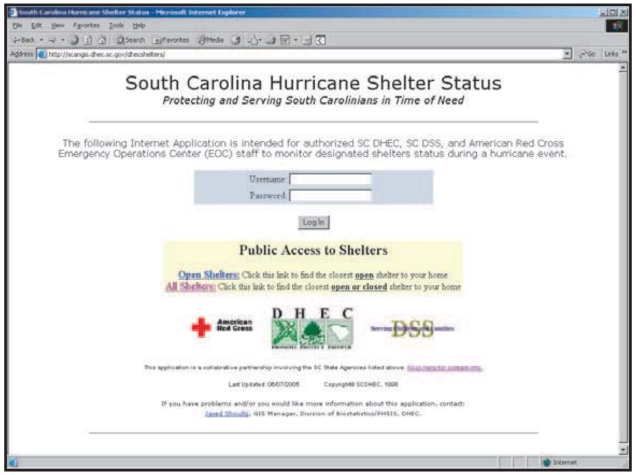


More than a dozen interactive datasets are made available on the South Carolina Community Assessment Network system.

Using ArcGIS and various extensions including StreetMap, along with the state E-911 street centerline file for accurate street data, users can create tables, charts, and maps according to their interests and specifications at the SC DHEC region, county, or ZIP Code level. Birth and death certificate data and demographics were the first datasets available on the South Carolina Community Assessment Network (SCAN) system (http://scangis.dhec.sc.gov/scan). Newer datasets include Pregnancy Risk Assessment Monitoring System, cancer incidence data from the South Carolina Central Cancer Registry, and more.

Each dataset has a series of pages related to it: Create a Table, Example, Definitions, Variable Information, Generate a Map, FAQs, and Links. The Generate a Map page allows the user to create interactive maps for any variables the user has selected. These maps display statistics the user has selected as well as supplemental reference information such as the location of health regions and facilities, major cities, and street networks. The user can ask questions about this data through the mapping interface to determine, for example, which counties have a population above a certain threshold or how many health facilities are in a specific user-defined area.

This Web site is also home to the Shelter Navigation system (http://scangis.dhec.sc.gov/dhecshelters), allowing authorized SC DHEC and Department of Social Services and the American Red Cross Emergency Operations Center staff members to monitor designated shelters' status during a hurricane. Residents of South Carolina can also use the public portion of the Web site to find open shelters closest to their homes along with driving directions.



The Shelter Navigation system allows authorized users to monitor the status of designated shelters during emergencies.

The site monitors approximately 280 shelters including 40 special medical needs shelters. As Hurricane Katrina evacuees came into South Carolina, they were immediately placed in shelters across the state. The system assisted disaster relief officials in placing them in shelters designated to meet their needs as well as keeping track of where the evacuees were placed.

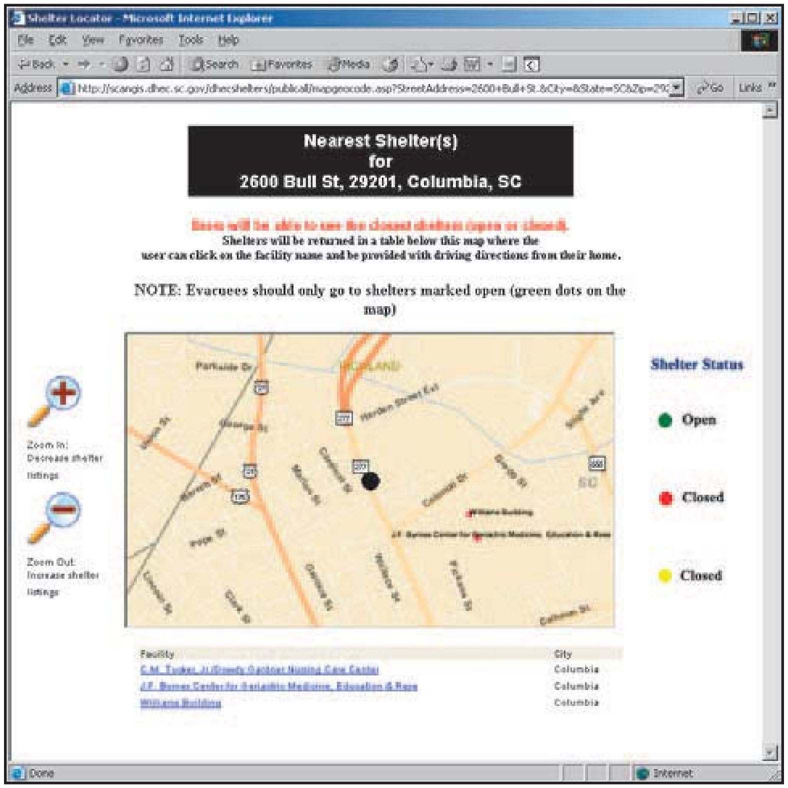
"Using the same software and server system to deal with emergency response and public health awareness allows us to make sure the systems will be ready when we need them," says Jared Shoultz, informatics manager, Division of Biostatistics and Health GIS, PHSIS, SC DHEC. "I always try to explain to people that if their emergency response systems are only used in an emergency, there is a good chance they will not work. Our system is hit every day through SCAN, more than a million times a year. When a crisis like Katrina strikes, we know we are prepared."

Results

The Division of Biostatistics and Health GIS serves as a model for GIS use. SCAN has proven to be an indispensable interactive data retrieval system for community assessment, planning, and health practices.

The GIS keeps data current and accessible. Before, it had been almost impossible to study health problems below county-level boundaries without expending a tremendous amount of time and manual labor.

(Reprinted from ESRI Case Studies 2005)

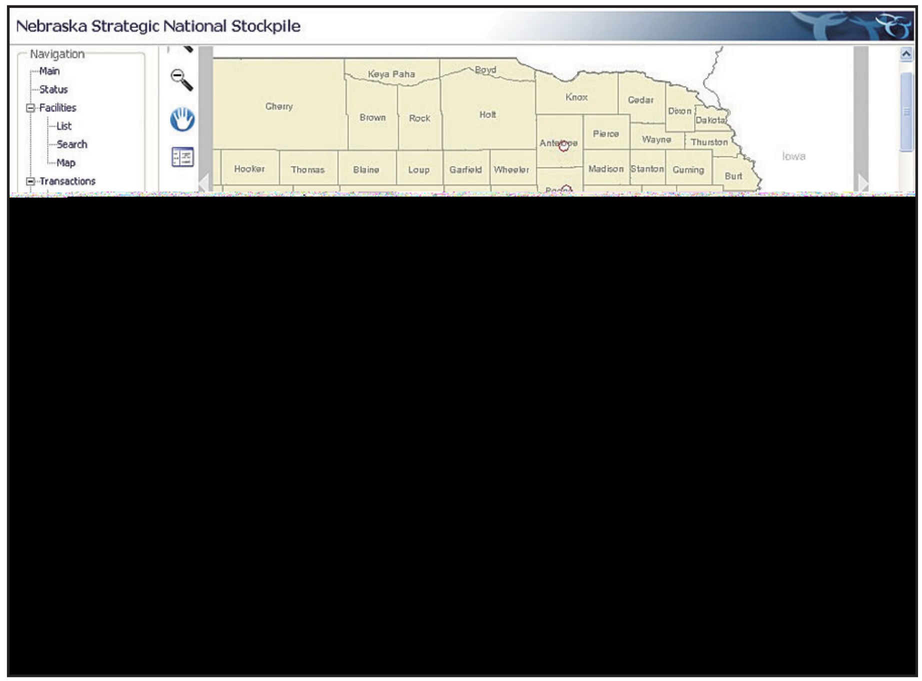


The Shelter Navigation system makes it easy for the public to find shelters, and SC DHEC can monitor and track shelters and evacuees efficiently when needed.

Health and Human Services Tracks Stockpile Shipments on the Web

Inventory Management and GIS Support Nebraska Preparedness

The Nebraska Health and Human Services System (NHHSS) is responsible for safeguarding public health in this midwestern state, famous for its cornfields and agricultural production. NHHSS responsibility includes preparing for and responding to catastrophic events that might affect the public's health. During such an event (e.g., a devastating tornado or flood), NHHSS personnel would work with the federal Centers for Disease Control and Prevention (CDC) to receive and distribute medical supplies and medicines from CDC's Strategic National Stockpile (SNS), a national repository maintained for just that purpose.



Stockpile Management Receiving and Tracking software, an application that combines inventory management and GIS technology, displays maps of Nebraska showing the location of state medical supply dispensing sites (Note: Facility names are not displayed for reasons of privacy.)

Timely action under such a scenario is an important aspect. Once federal and local authorities agree that the SNS is needed, medicines should be delivered to the state within 12 hours. The SNS program works with governmental and nongovernmental partners to upgrade their capacity to respond, and critical to the success of this initiative is ensuring that each state maintains a plan to receive, stage, and dispense SNS assets.

In preparing its plan, NHHSS decided to incorporate an inventory management application into the GIS technology it was already using for various health-related programs. "GIS is a powerful tool for public health and disaster response because visual representations of data help decision making, planning, and overall public health response efforts," says Keith Hansen, emergency response coordinator, NHHSS.

The new application would have to give NHHSS an efficient way to manage a sudden influx of supplies, aid in deciding where and how much to distribute to local receiving agencies, and track distribution. NHHSS collaborated with ESRI Business Partner GeoAge (Jacksonville, Florida) to develop what they called the Stockpile Management Receiving and Tracking (SMRT) application. NHHSS chose GeoAge because it has extensive experience in developing public health applications and proposed to build a stand-alone system that could be easily incorporated with the existing NHHSS GIS system.

For easy but secure access, SMRT was built as a Web-based system using ArcIMS, which NHHSS had experience with, and Microsoft .NET. NHHSS users can designate facilities at all levels from main hub to final dispensing site and record their locations. They can import inventory lists, create pick lists, manage users, and cross-reference information. When a specific state geographic area is affected, they can use the census population data layer to determine local population and thus calculate medicine dosage requirements for that area. Hub staff can create inventory transactions, record them geographically to determine where inventories are scheduled to arrive, then confirm that a shipment was received at the desired location.

"This is an extremely effective tool for the distribution and tracking of stockpile supplies," says Chris Chalmers, GIS coordinator, NHHSS, and director, GIS Public Health Research Program, University of Nebraska, "and it will help state and local health officials get the supplies to the areas of the state that desperately need them."

The application was tested in spring 2006 during a statewide TERREX 5.5 exercise headed by NHHSS in collaboration with CDC, GeoAge, and the University of Nebraska. More than 20 local health departments participated, as well as the Air National Guard; Crete Carrier transportation company; and the Nebraska Department of Roads, Emergency Management Agency, and State Patrol.

"Exercises like TERREX 5.5 don't happen overnight, and planning for this exercise began more than a year ago," says Chalmers. The scenario simulated a bioterrorism outbreak of pneumonic plague that spread quickly across the entire state. The Emergency Coordination Center served as the hub for emergency efforts and housed 30 computers with e-mail and Web access and a communication center with telephones, walkie-talkies, and satellite phones. The SMRT application ran alongside the existing NHHSS GIS used for everyday operations. High-resolution video projectors displayed detailed interactive GIS maps running ArcGIS Desktop (ArcInfo) with the ArcGIS Spatial Analyst and ArcGIS Network Analyst extensions. E-mail and activity logs were also displayed as events unfolded.

"During an emergency, communication and coordination are two of the biggest challenges to overcome," says Robert Leopold, deputy director, Regulation and Licensure, NHHSS. "GIS is an effective tool for enhancing the communication and coordination of multiple tasks to effectively respond to any public health emergency."

More Information

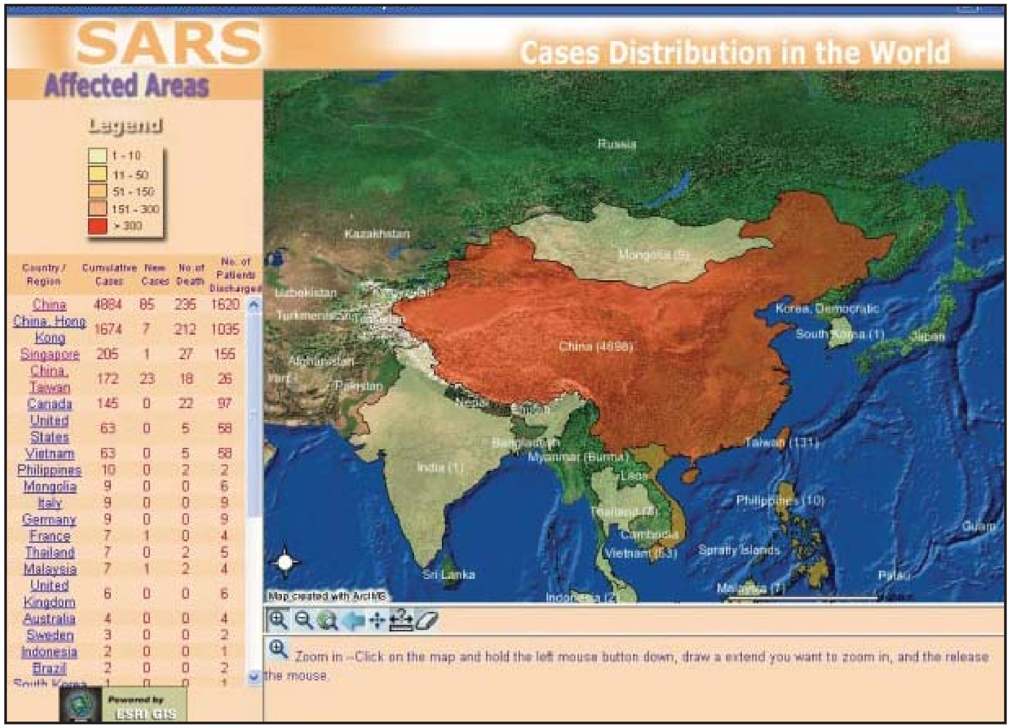
For more information, see the Nebraska Health and Human Services System Web page at www.hhss.ne.gov or go to www.geoage.com.

(Reprinted from the Fall 2006 issue of *ArcNews* magazine)

Tracking SARS in China With GIS

In late 2002, a new strain of atypical pneumonia was detected in southern China. By March 2003 the disease, now commonly known as Severe Acute Respiratory Syndrome (SARS), had spread around the world and would continue to cause suffering and widespread disruption for much of the next three months.

The epidemic claimed the lives of many people, required the enforced quarantine of thousands more, and brought upheaval and discomfort to literally millions. It had severe economic implications for countries in Asia and leading cities around the world.



A Web site established in Hong Kong tracked the locations of reported SARS cases worldwide. GIS allowed early recognition that a large multistory residential complex was a "reservoir" for the infection.

As the World Health Organization (WHO), governments, and health authorities throughout the world battled to understand and contain the epidemic, the fear, confusion, and limited access to reliable information worked to compound an already difficult situation. It rapidly became clear that the disease spread through proximity with infected carriers, and isolation either of individuals or whole buildings became the single most effective response.

The importance of location suddenly became very real to many people. Where were infected cases located? Which areas or buildings were free of the disease? More important, for speeding the return to normal life, which areas had been infected but were now declared clear?

In Hong Kong, initially one of the hardest hit areas, ESRI China (Hong Kong) Limited rapidly appreciated the value of GIS as a means of assembling and analyzing information on the spread and distribution of the disease. However, more than simply analyzing, Web-based GIS would make it possible to disseminate this information not only to the local population but to a global audience as well. As its contribution to a major effort by local businesses and community groups to respond positively to the emergency, ESRI China (Hong Kong) developed and hosted the SARS Mapping Web site.

Built on ArcIMS, the system was launched with both Chinese and English interfaces. It provided three basic views giving up-to-date accurate information on the distribution of the disease in Hong Kong, China, and the world, respectively. Daily updates from the China Center for Disease Control and Prevention (China CDC), Department of Health (DoH), Government of Hong Kong SAR, and WHO were collected, geocoded, and presented as online maps that could be interrogated, analyzed, navigated, and printed.

The Hong Kong SARS map page presented information on suspected, actual, and recovered SARS cases within Hong Kong. As part of its effort to provide clear, transparent data on the disease, DoH provided detailed information including a daily SARS bulletin, numbers and the status of patients, and the names of buildings in which infection had occurred. Every morning the SARS map team used DoH updates to geocode case information against Hong Kong street and building databases. This turned what had been tables of building names and statistics into data that could be intuitively presented, analyzed, and understood as a local map.

This display of China SARS distribution includes data on infected, suspected, and confirmed cases and the number of deaths.

Residents and visitors to Hong Kong could, therefore, easily check on the Web site which buildings in their neighborhoods had, or were suspected as having, infected cases and which had been cleared. Being able to see the information clearly presented on a familiar map helped alleviate a lot of the fear and concern of "not knowing" that had so disrupted normal life during the early days of the outbreak. The system also provided tools to highlight the most recent updates so people could monitor the spread of the disease and pace of recovery, as well as functionality to measure the distance between two buildings and check the number of infected cases within a given radius. In addition, the site provided summary views of statistics aggregated to administration regions.

The China and world SARS map pages were based on daily status reports from the China CDC and WHO. Information presented included the number of infected, suspected, and recovered cases as well as the number of deaths. Information for the China SARS map was aggregated to regional boundaries, while that for the world map was summarized by countries providing a global overview of the distribution of the disease.

The system, launched within a week of the outbreak occurring in Hong Kong, quickly became established as a center of information for both the public and press in the Asian region and throughout the world. At the height of the epidemic, the site was producing approximately 12,000 maps per day, and over the entire duration of the crisis produced more than 250,000 maps.

Dr. Heston Kwong, principal medical and health officer, DoH, comments, "Getting accurate information to the general public about the nature and spread of disease was absolutely essential. We posted daily status updates on our home page. We were delighted to see this data being presented through the SARS Mapping Web site. Being able to see the distribution of cases on the background of a familiar map and run spatial queries on the data provided another excellent channel through which information could be passed to the public."

The threat of SARS has, at least for now, subsided. On June 23, 2003, WHO removed Hong Kong from its list of areas affected by local transmission of the disease, and by the end of July 2003 all countries that had experienced the disease had been taken from this list. Many lessons have been learned in combating this disease including the importance of vigilance; clear and early notification of outbreaks; and accurate, open dissemination of information. It is also a reminder of the interconnected nature of today's world and the overriding importance of geography and location.

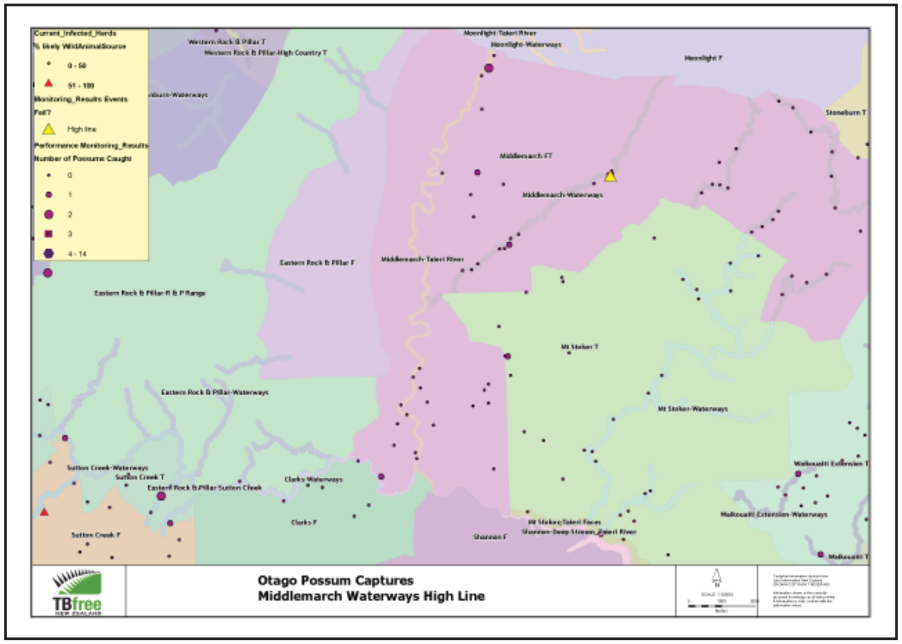
The SARS Mapping Web site was developed as part of the ESRI China (Hong Kong) ongoing program of serving the local community through the innovative deployment of GIS. The site was established and hosted as a voluntary initiative. Once the epidemic was over, the site was taken offline in August 2003. While it is hoped there will be no call to reactivate it, the site is ready if the need arises.

(Reprinted from the Summer 2004 issue of *ArcNews* magazine)

Consolidation of Information Makes Vector Control Data Accessible and Reduces Costs in New Zealand

In order to maintain its proud reputation as a supplier of high quality, healthy meat and dairy products, New Zealand implemented a comprehensive nationwide programme to control bovine tuberculosis in cattle and deer. Since the 1970s, New Zealand's government and farmers have spent more than NZ$1 billion managing the disease. To decrease its incidence and losses in agricultural production, the Animal Health Board (AHB) was created in 1998. It is a nonprofit, incorporated society with representatives from the farming sector and local government. Its current objective is to achieve official freedom from bovine TB in New Zealand by 2013.

The major cause of TB in cattle and deer herds in New Zealand is contact with wild vectors, mainly the introduced Australian brush-tailed possum. Intensive, large scale possum control programmes are therefore needed to prevent transmission of TB from possums to livestock.



ArcGIS allows AHB to share information about the locations and quantity of possum captures as part of its vector control programs.

The Challenge

To eradicate bovine TB in cattle and deer herds, AHB needed a technological system for sharing geospatial projects previously managed by local councils operating different types of data management systems.

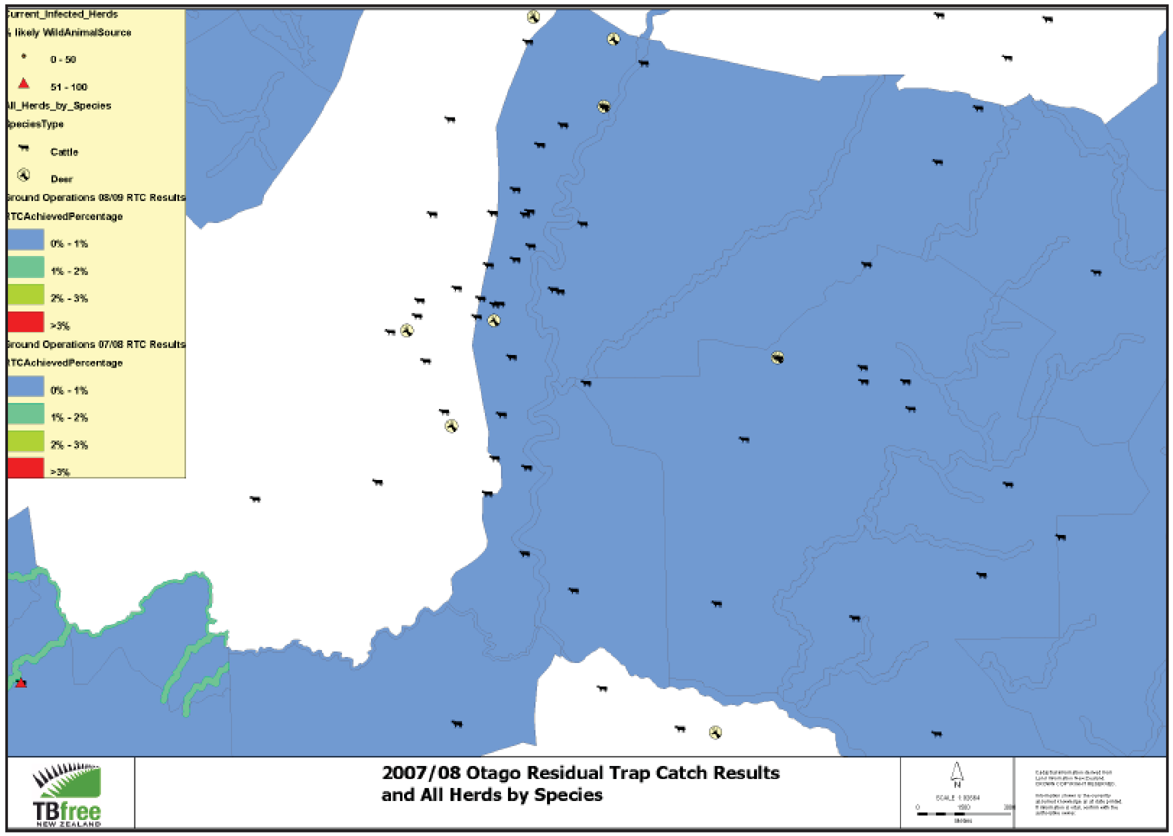
New Zealand needed to set regional and national targets for TB vector control, but was hampered by a lack of uniformity in capturing activity progress and results. Another difficulty was the fact that activities were scattered over a large area: more than 7,000 projects covering 8.4 million hectares. Before AHB took over the management of the vector control process, more than a dozen regional councils used differing methodologies to try to achieve this task. AHB took the best practices from these councils to develop business rules, procedures, and interfaces for a geospatial approach to vector control. This new approach would incorporate the local knowledge at the regional level and would centralize it at the national level. Operation managers needed to visualize possum densities in different areas, then link this to performance and financial data so they could identify the most effective control efforts. This information, sent by contractors in the field, needed to be uploaded and organized in a standardized manner so that managers could do spatial searches to aggregate data, prepare summary reports, and manage contracts. The solution had to ensure quality data could easily be entered by users to provide accurate results.

The Solution

AHB created VectorNet, an application that uses a map-based interface to access, query, and report on all aspects of AHB's disease and vector control processes. ESRI's ArcGIS software was tightly integrated into the application, built on .NET 2.0, and securely deployed over the Internet to multiple users. Eagle Technology Group, ESRI's New Zealand partner, provided the software. Functionality was progressively released in just 19 months. VectorNet links more than a dozen previously uncoordinated regional systems, creating consistent, accurate, and easy-to-manage geodatabases. Approximately 40 AHB staff use VectorNet for contract management, strategic planning, and reporting. Individual field contractors have the capability to update the database from the field with GPS-enabled handheld devices, then upload information through a Web browser to VectorNet. The data is validated and added to the geodatabase. Using a statistically based model to measure possum density, VectorNet generates exact locations within specific regions to implement control projects such as baiting or traplines. This geospatial approach, integrated with operational data, creates verifiable processes to better manage current projects and formulate future predictions. "VectorNet is a geospatial tool for designing, planning, contracting, and managing all the activities involved in the TB vector control program," says McCook. "Data collected is used to help make decisions on future operations and refine best practices."

The Results

Current spending on control of bovine TB is in excess of NZ$80 million per annum. AHB estimates that VectorNet will save NZ$30 million in its first decade. AHB also expects a net present value (NPV) of NZ$1.9 million for the GIS project. "A positive NPV shows that VectorNet is worth the investment of capital. We have calculated a payback period of 3.3 years," says William McCook, Chief Executive AHB, "but that's just the beginning. For instance, we expect a 1 percent [NZ$550K] efficiency gain on the overall vector program budget through consistent, accurate, complete, and timely information to make better decisions."



This map shows the geographic distribution of residual trap catch (RTC) results after completion of a vector control operation.

By making the link between geospatial and textual data and providing this information over the Internet, there is an increased visibility of decisions and improved access to information. This standardization also allows easier sharing of data with other organizations and establishes a connection of geospatial data with operational and financial information. "The model we have developed is robust and could easily be modified for managing other invasive species or diseases," shares McCook. "Other organizations could benefit from linking geospatial, operational, and financial data." AHB’s VectorNet, built on ArcGIS, received New Zealand magazine *Computerworld*’s 2008 Supreme Award for Overall Excellence in the Use of Information and Computer Technology (ICT) and the Award for Innovative Use of ICT. Its value was also recognized at the recent Asia Pacific Spatial Innovation Conference in Canberra.

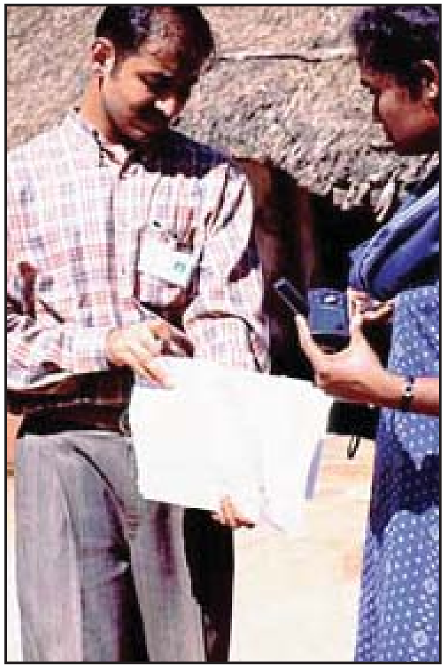
Learn more at www.esri.com/health.

(Reprinted from ESRI Case Studies 2009)

Down-to-Earth Approach Jumpstarts GIS for Dengue Outbreak

By Monica Pratt, *ArcUser* Editor

Armed with a handheld PC running ArcPad, a couple of GPS receivers, and a handful of volunteers, Dr. Jay Devasundaram developed a methodology for quickly generating a spatial framework for an Indian village that has also made decades of census data accessible. He hopes this process will jumpstart GIS use for addressing socioeconomic, environmental, and public health issues. This work also enabled GIS-based analysis of data gathered on a dengue fever outbreak.



Santosh S. Gad, a master's student at CMC, and Pearline Suganthy, a statistician on staff at CMC, were members of the team that captured GPS points for each house in the village.

Devasundaram, who holds a master's degree in public health in addition to a medical degree, was working as a consultant for ESRI Professional Services at that time. Trained as a physician at the Christian Medical College and Hospital (CMC) in Vellore, India, he has been involved in many aspects of epidemiology—in field-based leprosy control programs, in the physiology research lab at the National Institute for Mental Health and Neurological Sciences in Bangalore, and as a research fellow at the Center for Biomedical Engineering, Indian Institute of Technology in New Delhi. He has also worked for disease control programs for the State of Maryland and St. Mary's and Charles counties in Maryland.

Devasundaram has long been interested in the use of GIS for global disease surveillance programs and the development of GIS tools for health data collection and sharing. In fall 2001, a trip home to India to attend to family matters provided an opportunity to test a down-to-earth approach to GIS that he had been contemplating for several years. He felt that staff at CMC just needed a little assistance to implement a GIS that would benefit the institution's many holistic health programs so he paid for the needed GPS units out of his own pocket.

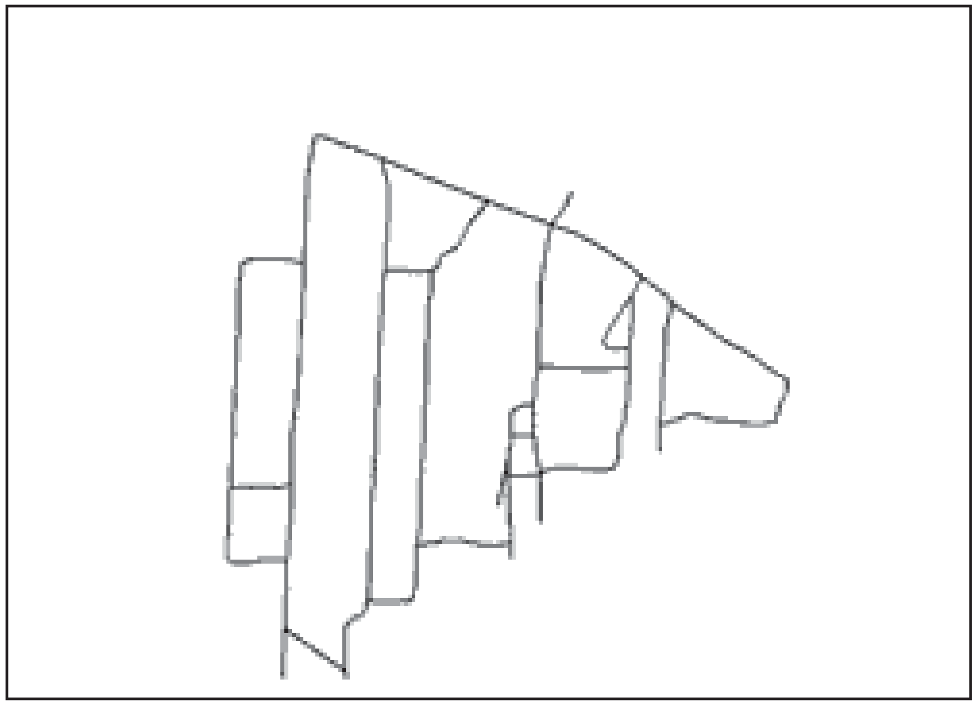
CMC is a prominent teaching and medical institution in India with a world-class reputation. Founded in 1900 by a young American missionary, Dr. Ida Sophia Scudder, CMC is a nonprofit organization located on a 2,000-bed multicampus complex. This institution pioneered many medical treatments—the first open heart surgery in India as well as India's first kidney transplant were performed there. The Community Health and Development (CHAD) program at CMC serves as the first referral unit for the inhabitants of Kaniyambadi block in the Vellore District and was recognized by the World Health Organization as a Center of Excellence for Community Health.

Dengue Outbreak

On September 1, 2001, a young man from Pennathur Village visited a CHAD outpatient facility complaining of a fever and nose bleeds and reporting that many people in his village were suffering from high fever. The next day, a team from CHAD visited Pennathur Village, a community of agricultural workers in the Kaniyambadi block, to assess the problem and institute appropriate control and preventive measures.

Anyone in the community who had developed a fever of any duration from August 1, 2001, onward was identified as a case. In this situation, in which more precise case definition involving labratory tests would have been prohibitively expensive, a house-to-house survey collected symptom information. An extensive questionnaire on each individual was filled out and demographic information including age, sex, and date of birth was obtained from an existing database at CHAD. Based on this information, the results of laboratory tests run on a small sample population, and entomological evidence, a dengue fever outbreak was declared. Of the 989 people living in Pennathur Village, 301 eventually contracted the disease.

Each year, tens of millions of cases of dengue fever (DF) occur worldwide as well as several hundred thousand cases of the more deadly dengue hemorrhagic fever (DHF). Of the five percent of cases that end in death, most are children and young adults. An occurrence of either DF or DHF is caused by one of four closely related but distinct serotypes of the genus *Flavivirus* (i.e., DEN-1, DEN-2, DEN-3, and DEN-4). Immunity acquired for one serotype does not protect an individual from other types. Consequently, a person living in a dengue-endemic area can potentially suffer four episodes of the disease during a lifetime. The disease is transmitted to humans via a day-biting mosquito, *Aedes aegypti,* and the rate of infection typically increases with the beginning of the rainy season.



Dr. Jay Devasundaram generated a street centerline file by simply walking through the streets of the village using ArcPad with a GPS receiver.

Mapping the Spread of Disease

Although mapping in public health is more than 150 years old, public health GIS applications are relatively recent. More than just the display of data, these applications include the storage, integration, and analysis of spatially enabled health data. Of all the areas of public health, GIS use for epidemiology is most widespread.

Because no vaccine is currently available for DF or DHF, mosquito control that reduces larval breeding sources represents the most effective available long-term prevention measure. However, in the short term Devasundaram believes the development of improved, proactive, laboratory-based surveillance systems that provide early warning of impending dengue epidemics will allow the public to be alerted and aid physicians in correctly diagnosing and treating dengue/DHF cases.

Devasundaram spatially enabled the data collected on dengue fever outbreak by generating a basemap for the village in a period of about five days. Simply walking through the streets of the village, he used ArcPad with a GPS receiver to generate a street centerline file. Next, a small team of CMC students and staff captured GPS points for each house in the village. This five-day period also included much time spent standardizing the data collection process and teaching it to volunteers.

In a part of the world where street addresses suitable for geocoding are virtually nonexistent, unique house numbers assigned as part of the National Malaria Control Program (NMCP) provided a built-in key to unlocking census data and organizing new attribute data. Later renamed the National Malaria Eradication Program (NMEP), it was instituted in 1953 in response to a severe outbreak of the disease. Using house numbers, Devasundaram could not only explore data on the dengue outbreak but could also integrate the detailed census data that has been collected by the Government of India since 1872.

Adding Analysis Tools

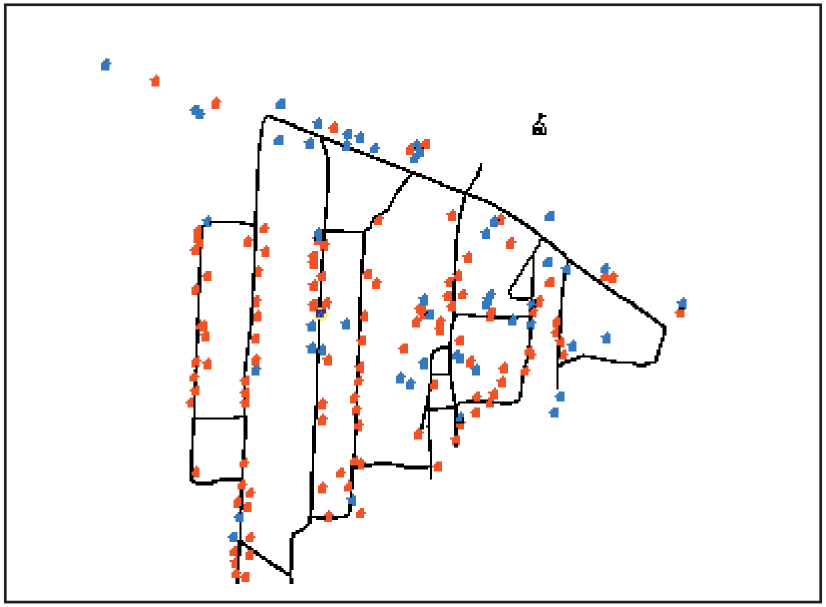
Upon returning to Redlands, California, Devasundaram worked with fellow ESRI staff member Tanya Costain who developed an ArcGIS application that incorporated one of the classic tools for epidemiological analysis—the two by two contingency table—which is used to evaluate both cohort and Case-Control studies. This table can be used to generate Relative Risk (RR) and Odds Ratio (OR), two measures of association between exposure and the occurrence of disease, used along with confidence intervals as tests of statistical significance.

	Disease	No Disease	
Exposed	A	B	Disease Total
Not Exposed	C	D	No Disease Total
	Exposed Total	Not Exposed Total	TOTAL

A two-by-two contingency table is used to evaluate Relative Risk (RR) and Odds Ratio (OR).

RR is a ratio of occurrences of the disease in the exposed population relative to occurrences of the disease in the unexposed population. It is computed using the formula A/(A+B)/(C/C+D) and is applicable to Cohort studies that have incidence data. If RR equals 1, there is no association between exposure and the disease. If RR is greater than 1, exposure is associated with increased incidence of the disease. If RR is less than one, exposure is associated with reduced incidence of the disease. When incidence measures are not available, as in Case-Control or retrospective studies, OR is used. It is calculated from the contingency table using the formula A * D/B * C.

Costain created a custom tool using Visual Basic and ArcObjects that allows exposure parameters, such as type of housing or age, and other relevant epidemiological attributes of features interactively selected by the user to be analyzed in a contingency table. The tool populates the table and calculates RR and OR. Clicking on a cell in the table will display the associated features on the map. Another tool generates a graph that shows the occurrence of the disease over a specified time frame. Jennifer Cadkin, also of ESRI, subsequently added history tracking functionality that allows analyses to be saved and revisited.



A team from CMC gathered coordinates for each house in the village.

Summary

Incorporating traditional epidemiological statistical techniques into a GIS interface allows researchers to gain a greater insight into the spatial aspect of the spread of disease. The pilot spatial framework creation project demonstrated just how much can be done in a short time with little funding.

By using a "hard core" approach to data collection, Devasundaram believes the volunteers, several of whom are students, will really understand the data and not be reliant on outside sources for it. "There is a whole culture one needs to build. Nothing works without data behind it," said Devasundaram. With this spatial framework in place, they will be better able to address the area's many environmental and socioeconomic issues that are manifested as public health problems. "You can't isolate these things. If you do the socioeconomic work, health will follow," said Devasundaram.

(Reprinted from the January–March 2003 issue of *ArcUser* magazine)

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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. 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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