Mobile GIS for Public Health Preparedness and Response
Mark H. Smith, Ph.D.

Abstract

North Carolina's Office of Public Health Preparedness conducted a two-year pilot project to replace traditional paper-based field data collection methods with mobile GIS applications. The methodology deploys multiple field teams equipped with pocket PCs running ArcPad, StreetMap USA, and GPS receivers. Data collection forms are customized using Application Builder and installed on the handheld computers. Field teams are routed to their locations using StreetMap USA. When the geographic location is recorded using the GPS unit, the form opens automatically. Field teams return to the staging area where data are uploaded wirelessly to a database on a laptop computer for quick analysis. This method has been used for a Rapid Needs Assessment after Hurricane Charley and for a Legionnaire's Disease outbreak in Western North Carolina. The mobile GIS approach to field data collection has been so successful that NC is providing funding in 2005 to expand the pilot project into a statewide bioterrorism special project.

Project Goals and Objectives:

To improve the capacity of NC Public Health to respond to bioterrorism, natural disease outbreaks, and natural disasters through the use of GIS, GPS and electronic field data collection using handheld computers.
To develop the capacity of Public Health Regional Surveillance Teams (PHRST) to rapidly respond to bioterrorism or naturally occurring health emergencies via geocoded field data collection and electronic transmission of data to regional and state databases for analysis.
To develop a set of customized data collection forms that can be used in various bioterrorism and other public health applications in NC and elsewhere.

Background and Significance:

In response to the terrorist attacks of 9/11/2001 and the subsequent anthrax attacks, the State of NC established the Office of Public Health Preparedness and Response (PHP&R) in early 2002. PHPR created seven regional bioterrorism preparedness and response teams—Public Health Regional Surveillance Teams (PHRST)-- hosted by county health departments. In the fall of 2002, PHRST-5, in collaboration with the Guilford County Department of Public Health, initiated a pilot project to use GIS and GPS to enhance bioterrorism response capacity.

Specifically, PHRST-5 obtained an ESRI industry Homeland Security grant of desktop GIS software and 20 copies of ArcPad GIS mapping software for Pocket PCs running Windows CE operating systems. Copies of ArcPad were made available to county Health Departments in Region 5 that used Homeland Security Aid-To-County funds to purchase IPAQ Pocket PCs and GPS units. PHRST-5 staff provided training in the use of the IPAQs, ArcPad and GPS. PHRST-5 further collaborated with the Emergency Programs Office of NC Department of Agriculture and Consumer Services to develop outbreak investigation forms for the IPAQs and to access their Multi-Hazard Threat Database (MHTD) and interactive mapping server.

In the fall of 2003 the concept was put to the test during NC's Triple Play bioterrorism exercise simulating a pneumonic plague outbreak—in humans and animals—in Greensboro, NC. The PHRST-5 team operating out of Greensboro received scores of simulated case reports. PHRST-5 staff and Guilford County bio-team members used a combination of desktop PCs, notebook PCs equipped with wireless cards, and IPAQs similarly quipped with wireless cards to upload case locations and data to the MHTD interactive map server. Significantly, the exercise also demonstrated the capability to go into the field—simulating outbreak contact tracing—to collect patient data on installed ArcPad forms on the IPAQs, with GPS units, and wirelessly send those reports directly to the MHTD. These data were then available to the state epidemiologist and incident command in Raleigh to respond to the outbreak more effectively.

Customized ArcPad form installed on Pocket PC equipped with GPS Receiver, Expansion Pack and Wireless Aircard

Rapid Needs Assessment after Natural Disasters: In September of 2003, PHP&R, guided by a team from CDC, conducted Rapid Needs Assessment (RNA) in the wake of Hurricane Isabel. The assessment methodology used a two-stage cluster sampling method to randomly select 30 census blocks in the affected area and then sample seven households within each block where field teams interviewed householders relating to damage from the hurricane. The survey responses were then generalized to the overall population of the assessment area to inform public health and emergency response efforts. The methodology employed for the Isabel RNA used a laborious procedure to identify the geographic sampling areas and used paper questionnaires in the field, necessitating double data entry.

Given the encouraging experience during the Triple Play exercise of using GIS, GPS and handheld computers to collect data in the field effectively and communicate it for rapid analysis, PHP&R's RNA Epi-Team set out in early 2004 to enhance the methodology employed after Hurricane Isabel, working closely with PHRST-5 on the project. PHRST-5 collaborated with the University of NC at Greensboro to establish a 0.5 FTE graduate research assistantship filled by a Masters student in Geography. The graduate research assistant worked with a

technical consultant to help develop specialized RNA forms installed on the IPAQs, along with innovative uses of GIS to speed the RNA process.

ArcView Used to Select Geographic Sampling Units in the Rapid Needs Assessment

In August 2004 the new methodology was tested by conducting RNA in the aftermath of Hurricane Charley's pass through the coastal counties of NC. The RNA Epi Team used desktop GIS in conjunction with other software to randomly select 30 block groups in the three-county assessment area. Within each block group a "random point in polygon" script was applied to select seven points. Those points were then downloaded onto one of ten IPAQ Pocket PCs installed with an RNA survey form and ESRI's Streetmap program that converted the points into stops on a route. Using the ArcPad software, GPS and Streetmap for routing to the households to be surveyed, the field personnel would click on the GPS button in ArcPad to collect the geographic coordinates and automatically open the RNA form. Ten field teams took the IPAQs into the field and completed the surveys within the same day. Upon return of the IPAQs to the staging area, the data from each unit was uploaded to an Access database and then exported into Epi-Info for analysis

Each of the ten field interview teams included at least two persons, one of whom carried a clipboard and filled out a paper interview form; the other team member conducted the interview using the handheld computer. This provided a paper backup in the possible event of loss of data from the IPAQs as well as a comparison of the two methods in terms of ease of use. The handheld users generally liked that the drop-down menus and other form design features of the IPAQs. Incorporation of required fields into the electronic forms prevented users from prematurely saving an incomplete form. It was commonly reported that at first the team member filling out the paper form was faster, but that after a few interviews the handheld computer user could complete the form as fast or faster. An examination of the dataset revealed that all of the surveys were successfully uploaded, with very little missing data.

One of the important issues that arose in deploying the new technology into the field was that the technology was so new that there were only a few public health personnel available who knew how to use it. Before survey teams could take handheld computers into the field, it was necessary to conduct a two-hour training session the evening before and another one-hour

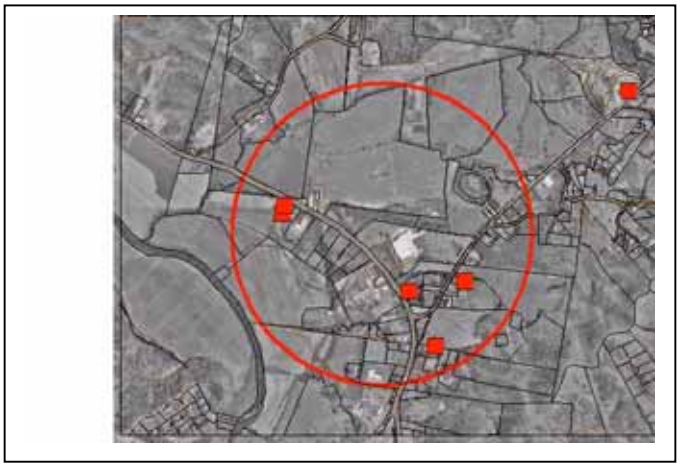
training on the morning of the field interviews. In addition to the necessary training on the interview form, users were trained in the basics of using an IPAQ 5450, using the ArcPad GIS software, completing the electronic form, and the use of the GPS unit for navigation and geo-referencing the data. Had a cadre of public health personnel previously received training in these areas, preparation time for the RNA would be significantly reduced.

Legionnaires Disease Outbreak Investigation

In October of 2004, PHRST-5 was requested by PHPR to mobilize to Cherokee County in Western North Carolina to assist in a Legionnaire's Disease outbreak investigation underway, a collaborative effort of the local health department, PHPR and the CDC Epi-Aid team.

The Legionnaire bacterium was identified in the cooling tower of a factory in the county. The investigation design was to conduct a survey with all adult residents living in a half-mile radius of the cooling tower. ArcView GIS software was used to create a half-mile buffer around the cooling tower and to map neighborhoods within this survey area to assist field interviewers to navigate to households to conduct interviews. PHRST-5 provided nine handheld IPAQ computers equipped with GPS and installed survey forms. Seven field interviewers from the CCDPH used lists of residents and maps to navigate to the houses where interviews were performs. The PHRST-5 team leader provided mobile technical support to field interviewers, who communicated questions or problems to the command center and to tech support via radio. A laptop computer was situated in the command center to receive data from field interviewers. As interviewers returned to the command center, each IPAQ was connected to the laptop and the survey data were uploaded to an Access database. The database could then be opened immediately for visual examination of the data. When all data were uploaded to the database, a copy of the dataset was provided to the CDC Epi-Aid team for analysis.

Due to the ability to view the data immediately upon return of interviewers from the field, investigators were able to quickly conduct chart reviews for all persons reporting that they had been diagnosed with pneumonia during the previous twelve months. Use of the handheld computers for data entry meant that data needed to be entered only once. The duration between data collection and analysis was greatly reduced. The ArcPad GIS software running on the handheld computers saved the data in a format that made it easy to upload the data either into statistical analysis programs or a GIS mapping program for geographic analysis of the data.



Survey Area, One-Half Mile Radius from Factory Cooling Tower, and Pneumonia Cases Identified.
Cherokee County, NC

Implementing Electronic Field Data Collection Technology Statewide

The benefits to public health preparedness and response of electronic field data collection were demonstrated during the Triple Play plague exercise, the realistic conditions of the Hurricane Charley Rapid Needs Assessment, and the Cherokee County Legionellosis outbreak investigation. It is easy to envision many other applications of this technology relevant to bioterrorism or other public health preparation and response. For example, the use of handheld computers could enhance surge capacity, improving the efficiency of mass vaccination and prophylaxis events. Should a mass epidemic or bioterrorism event require the mobilization of the Strategic National Stockpile (SNS), handheld computers equipped with bar code scanners could speed patient processing, protecting patient safety by reducing medication errors.

Georeferenced electronic field data collection functions in the nexus of multiple cutting edge technologies: 1) GIS software for Internet, desktop and handheld computers; 2) Global Positioning System (GPS) capabilities; 3) Powerful handheld computers running Windows operating systems; 4) wireless data transmission technology, including Bluetooth and WIFI (802.11b/g); and 5) database systems and data analysis software. Fielding multiple outbreak investigation teams equipped with handheld computers, customized survey forms, and GPS units requires not only investments in the hardware and software but also extensive investments in application development, knowledge acquisition and dissemination through training and education.

In early 2005, the NC Office of Public Health Preparedness and Response authorized funding for to convert the two-year regional pilot project into a statewide demonstration project—called the Rapid Response Project, or Project 516 due to its budgetary designation--integrating GIS, GPS and electronic field data collection into public health preparation and response at the local, regional and state levels. The project will include the following components:

1. Establish a project advisory committee.
2. Extend electronic field data collection capability to all seven PHRST regions and the Raleigh office of PHP&R. Conduct an assessment of each PHRST region to identify capacity in GIS, GPS, wireless communications systems, and database systems. The assessment will identify potential collaborations between PHRST teams and universities, colleges, other regional agencies, and county agencies with GIS capabilities. These assessments will help determine where field data collection hardware and database systems should best be located, and which personnel should receive training. Equip each PHRST region and PHPR with multiple handheld computers, GPS units, and GIS software for desktop and handhelds, along with training in the multiple technologies involved. The goal is that each of the seven PHRST regions will develop the capacity to provide GIS and field data collection and analysis services to local health departments and other health system or emergency response agencies.
3. Develop and promote protocols for accessing state public health and emergency response database and analysis systems. In particular, work with the NC Department of Agriculture and Consumer Affairs Emergency Programs Office to develop regional and local access to the Multi-Hazard Threat Database, to provide rapid transfer of geo-referenced field data to state health officials, epidemiologists and emergency response officials. Project staff will work with the Emergency Programs Office and technical consultants to develop a push-pull data capacity: 1)

new data collection forms can be developed “on the fly” at the local level and then uploaded to regional or state databases after data collection, or 2) state epidemiologists can work with PHPR and MHTD staff to create new data collection forms and then “push” them out via the internet to be downloaded by local field data collection teams.
4. Establish two Public Health GIS Research Assistantships at the University of North Carolina at Greensboro and North Carolina State University. Assistantship will be established through NC State University. Graduate research assistants will provide technical support, application development, and training services to the project.
5. Develop and provide targeted and specialized training for project participants. Project staff will collaborate with faculty from UNC-Greensboro Department of Geography and other project collaborators to develop training programs in GIS for Public Health and Field Data Collection.
6. Develop and disseminate a set of customized data collection forms for Rapid Needs Assessment, outbreak investigation, mass immunization clinics, and other public health field data collection needs.
7. Implement system tests and exercises at the regional and state levels on the use of electronic field data collection for Rapid Needs Assessment, outbreak investigation, and Strategic National Stockpile/mass prophylaxis.
8. Disseminate knowledge, data collection forms and training tools developed through the project.

Contact Information

Dr. Mark H. Smith
Guilford County Heath Department
Public Health Regional Surveillance Unit 5
1203 Maple Street
Greensboro, NC 27405
US
336.641.6844
msmith@co.guilford.nc.us