GIS Technology and Applications for the Fire Service

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GIS Technology and Applications for the Fire Service

The mission of the fire service is to protect life, property, and natural resources from fire and other emergencies. With increasing demands, the fire service must utilize the best tools, techniques, and training methods to meet public expectations. Risk management, preparedness, and mitigation have taken on new importance with challenges facing the fire service today. Effective response cannot be continually achieved without adequate planning and preparedness. One of the emerging tools that is helping the fire service optimize its emergency services delivery is geographic information system (GIS) technology. GIS supports planning, preparedness, mitigation, response, and incident management. GIS extends the capability of maps—intelligent, interactive maps with access to all types of information, analysis, and data. More important, GIS provides the required information when, where, and how it is needed. This paper will examine how GIS technology is helping the fire service meet the needs of the community more efficiently than before.

Introduction

When a fire occurs, any delay of responding fire companies can make the difference between the rescue of occupants versus serious injury or death. The critical time between fire containment and flashover can be measured in seconds. Fast access to critical information is essential. Tools that help firefighters pinpoint the emergency call location, assess the potential consequences, and determine the most efficient strategy will minimize property damage and better protect the safety of occupants and fire service personnel.

Historically, first responders have relied on experience, good equipment, communication, and teamwork to achieve successful emergency response. However, with all the challenges confronting emergency crews today, effective response requires good planning, risk management, comprehensive training, and intelligent deployment through preparation. GIS technology has become a powerful tool for improving all aspects of fire service delivery systems.

As populations and building development increase, the role of the fire service becomes more demanding and complex. As never before, fire departments are being called upon to deliver services with greater efficiency and economy. Citizen tax-reduction initiatives, burgeoning needs for different kinds of local government services, and a host of other factors have brought new demands to the desks of fire chiefs—most notably, the demands to "do more with less" and to do it "better, faster, and cheaper." GIS technology brings additional power to the process whereby hazards are evaluated, service demands are analyzed, and resources are deployed. In addition, GIS contributes to the speed with which emergency responders are able to locate, respond, size up, and deploy to an emergency.

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Fire officers are continually collecting data from a wide variety of sources to better perform their jobs. This data may come in many incompatible forms. By utilizing GIS, data can be quickly analyzed and displayed in different arrangements to allow patterns and trends to emerge. Fast access to needed data can save time, money, and lives.

What Is GIS?

A GIS is a computer-based technology that links geographic information (where things are) with descriptive information (what things are like). GIS is used to capture, display, and analyze data spatially. GIS combines layers of information about a place to give users a better understanding of that place. Unlike a flat paper map, a GIS-generated map can present many layers of different information that provide a unique way of thinking about a geographic space. By linking maps to databases, GIS enables users to visualize, manipulate, analyze, and display spatial data. GIS technology can create cost-effective and accurate solutions in an expanding range of applications. GIS displays geographic data as map layers. Some GIS map layers fire departments use include

- Streets
- Parcels
- Fire hydrants
- Utility networks
- Topography
- Lakes and rivers
- Commercial and government buildings
- Fire station locations
- Police station locations
- Hospital locations
- School locations
- Satellite or aerial imagery
- Historical incident or emergency call locations
- Fire demand zones
- Public occupancies

These map layers can be selected and displayed (overlaid) by a GIS user. These map layers are linked to data tables that contain detailed information about the geographic features being displayed. For example, a parcel layer may contain various attribute information such as

- Owner
- Value
- Zoning class
- ZIP Code
- Address

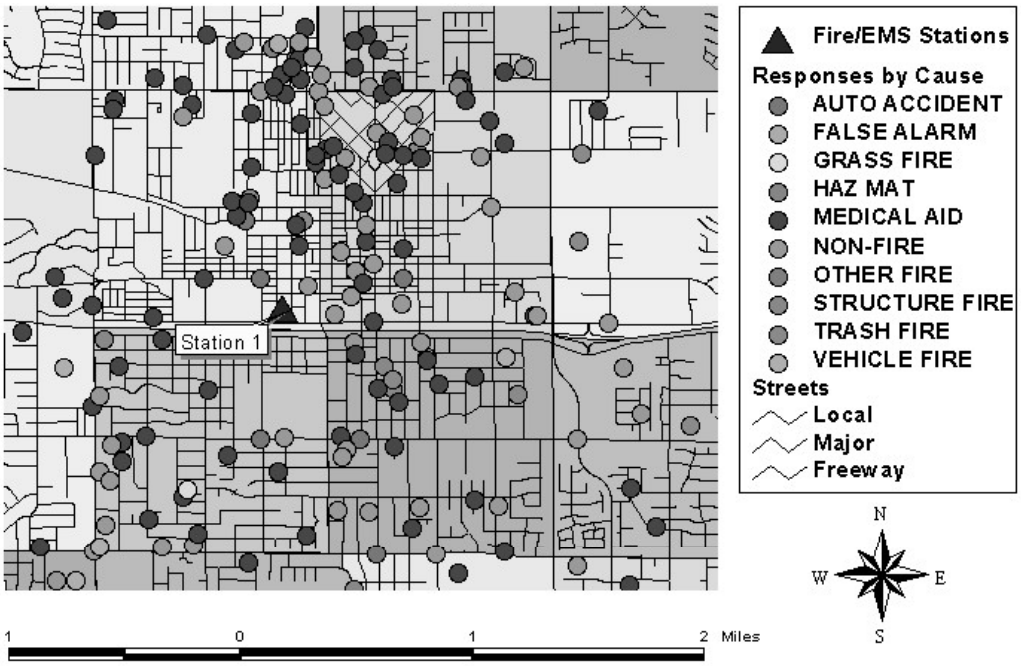
A map layer of historical incidents (represented by points or icons) consists of attribute information for each incident, which may include

- Incident type
- Incident cause
- Date of incident
- Time of incident report

- Units that responded
- Unit arrival times

This attribute data allows GIS users to perform complex analyses. GIS makes map displays interactive and intelligent. For example, a GIS user could begin to analyze and display incident trends. A spatial query could request incident locations by cause, time of day, specific geographic locations, and so forth. GIS searches the data tables, gathers the data that matches the spatial request, and displays it on the map. Incident trend analysis can be done quickly, displayed logically, and understood easily. These types of analyses provide decision support information for issues related to fire prevention, staffing requirements, and apparatus placement/deployment.

Figure 1
Incidents during March



Historical incidents accessed from the records management system are displayed in GIS.

Using GIS for Complex Analysis

Response Time Modeling

Utilizing a fire station layer and a street layer, response time analysis can be performed. A street layer is often represented in GIS as a series of lines that intersect on the map, creating a GIS network. Each street line segment between intersections can contain the road type, distance, and travel speeds (miles or kilometers per hour) permitted in the underlying data table within GIS. This allows users to identify a station location, specify a travel time, and run a network analysis. The result will be illustrated by an irregular polygon around the station that closely approximates where a fire apparatus could travel in any direction for the specified time. This type of analysis could be performed

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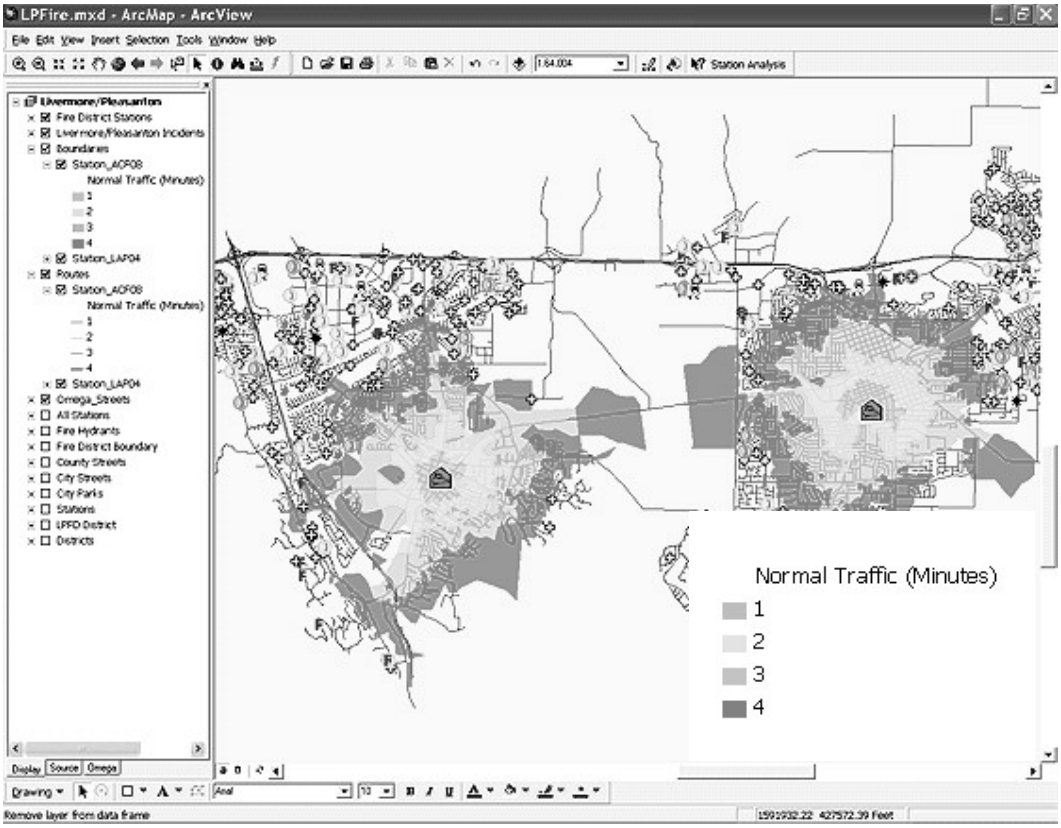
simultaneously on all the department's stations to analyze gaps in coverage, run orders, and so forth.

Figure 2



This map illustrates various drive times by color code from station sites.

Incident Trend Modeling

Incident trend analysis is a common practice by fire departments. With GIS, incident trend analysis can be performed quickly with all the relevant information. GIS can access and "geocode" (place a point on the map) historical incidents. This capability can be refined by conducting a spatial query to the records management database that specifies the type of incident, time range, or specific geographic area. For example, a GIS user could request to see arson fires that occur between the hours of 1:00 a.m. and 5:00 a.m. on Saturdays in fire districts 1 and 2. GIS will interrogate the records database and place points on the map that meet this request. The GIS user can access all the information concerning each incident by simply clicking on the incident point. GIS can add additional information by displaying the demographics for each of the two fire districts identified in the spatial request.

Event Modeling

Event modeling allows the user to identify a location (factory, hazardous material location, rail track intersection, etc.), place a point on the map, and run a selected model. Models could be anything from plume dispersion to an explosion. GIS can display the model on the map; delineate various levels of danger; and identify exclusion zones, infrastructure damage, and population effects. In addition, road closure requirements,

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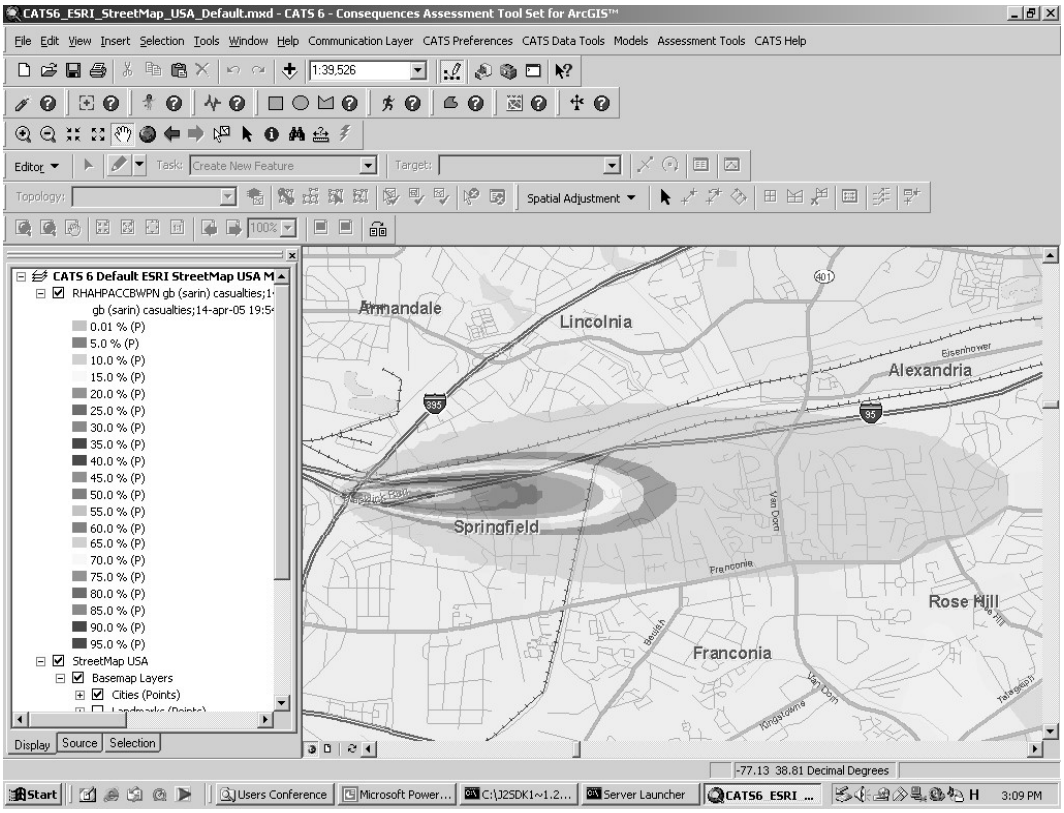
safe routes into and out of the hazardous area, and appropriate hospitals that could quickly service the emergency can be displayed along with other information for emergency decision support. Modeling can be used for analyzing vulnerabilities, preplan development, training, or communicating with the public and policy makers.

Figure 3



This map illustrates a sarin gas plume model and color-coded areas of concentration.

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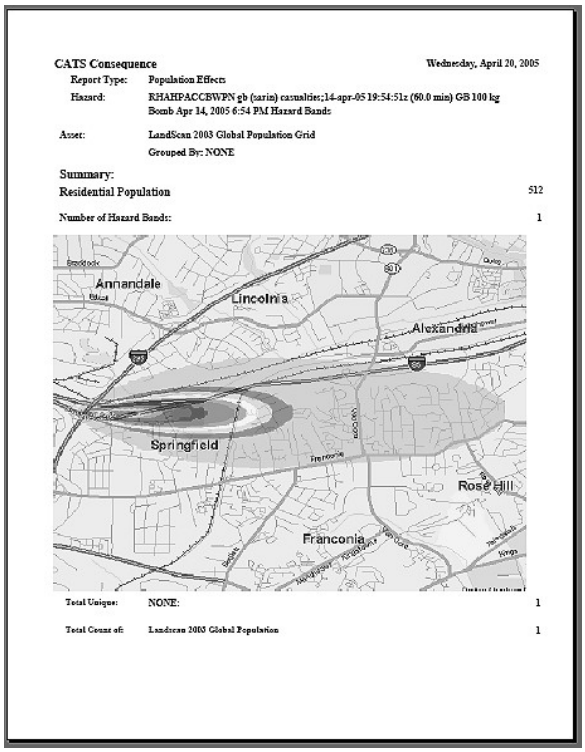
Figure 4



CATS Consequence — Wednesday, April 20, 2005

Report Type: Population Effects

Hazard: RHAHPACCBWPN gb (sarin) casualties;14-apr-05 19:54:51z (60.0 min) GB 100 kg Bomb Apr 14, 2005 6:54 PM Hazard Bands

Asset: LandScan 2003 Global Population Grid

Grouped By: NONE

Summary:

Residential Population	512
Number of Hazard Bands::	1

Total Unique:	NONE:	1
Total Count of:	Landscan 2003 Global Population	1

A Quickly Generated Map and Report with Residential Population Effects

GIS for Centralizing Data

GIS can become a central repository for a variety of nonspatial data. Nonspatial data, such as floor plans (computer-aided design drawings), photographs, preplans, and other documents, can be linked to features on the map (documents or photos that pertain to a particular building location or other actual feature location). This information, when configured with mobile computers, can provide first responders with information essential when sizing up for deployment.

Historically, GIS required having software and data on a computer with a trained GIS technician. Today, newer GIS application software has evolved and can operate effectively in a networked or Web-based environment. GIS software can reside on a Web server, the GIS data can be in several different locations or other Web servers, and users can access the GIS application through a Web browser. Web-based GIS services make it possible to deploy regional GIS applications and dramatically reduce costs and maintenance.

GIS is rapidly becoming a standard technology for many industries. The remainder of this section will examine how GIS can be and is being used in all aspects of fire and emergency services.

Computer-Aided Dispatch

Dispatchers have an important responsibility to process emergency calls and send the appropriate public safety resources to the emergency location based on the type and urgency of the incident. GIS is an important component of the dispatch system. Dispatch systems or computer-aided dispatch (CAD) systems typically contain a file

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called the Master Street Address Guide (MSAG). This file contains street address information and service areas for the jurisdiction that the dispatch center services. As emergency calls are received, they may be accompanied with address information from the telephone company's emergency phone record database. This address is entered or electronically transferred to the CAD system, which compares it to the MSAG. When the address is matched, the specific service area is also identified with the specific units that should be dispatched to the emergency. If the telephone company does not provide a digital address with the call, dispatchers must obtain it from the caller and type it into the system.

Many computer-aided dispatch systems have begun to integrate GIS technology. GIS takes the address and automatically geocodes the incident and displays it on a map. There are several benefits of having the incident displayed on a GIS map. New calls reporting the emergency may have different addresses but are reporting the same incident that was previously recorded. The GIS map display will illustrate that even though it is a different address, it is in the same proximity as the original call. Other benefits include

- Global positioning system (GPS)—Many public safety agencies are equipping response units with GPS devices. This provides the dispatcher (and perhaps other appropriate public safety managers) the ability to see locations of units through a GIS display and track them to the incident when dispatched. This is important during heavy call volume or for mobile vehicles such as police units and emergency medical units. This provides dispatchers a virtual or near real-time view of incident locations and emergency response units to activate an appropriate dispatch based on emergency unit availability.

- Routing—GIS can quickly analyze and display a route from a station or GPS location to the emergency call. This route (depending on the sophistication of the street file) may be the shortest path (distance) or the quickest path (depending on time of day and traffic patterns). This information can be displayed to the dispatcher and on a mobile computer screen in the response vehicle. Vehicles equipped with mobile computers and GIS can also benefit by providing first responders with access to preplans, hazardous material locations, photographs, and other location-based documents linked to actual specific locations through the GIS map display.

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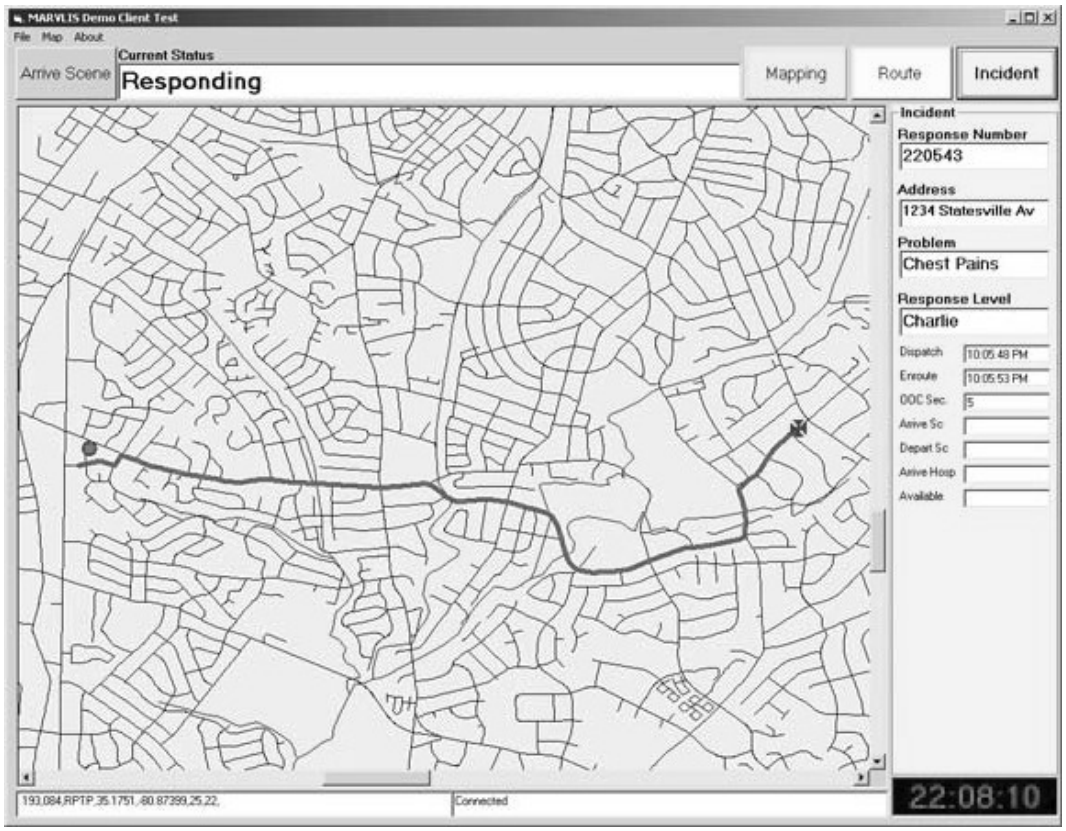
Figure 5



Address and quickest route to the incident can be displayed on the mobile computer terminal within the EMS unit.

- Move up and cover—During periods of high volume and simultaneous calls or a complex emergency, GIS can display areas of high risk that are left substantially uncovered. GIS can provide recommendations for reallocating available resources for better response coverage.

- Emergency wireless calls—Wireless technology and cellular telephone technology has added to the necessity of GIS. Wireless phone-reported emergencies are not associated with an address, and the caller may not know his or her address or street location. GPS-enabled cell phones can provide latitude and longitude coordinates during an emergency call. Other technologies are available that triangulate the call location between cell towers or measure the strength of the signal to provide approximate location information. These coordinates are relatively meaningless to a dispatcher, but GIS can quickly consume and display a latitude/longitude or other coordinate location. This enables the dispatcher to see the incident location or general area and the closest or quickest response units on the GIS display.

- Records management system—Dispatch systems often have a database to capture, store, and archive incidents. This database may be called a records management system or a CAD records system. The records stored in this database concerning emergency calls usually contain location information. GIS can link to and geocode

the location that represents this event. These events can be analyzed and assessed by any field in the records database (time, incident type, etc.). GIS provides a powerful capability to see, understand, and assess a department's volume of business, developing trends, and response performance. The investment and information within a records management system can be leveraged for additional purposes when geospatially enabled.

Planning

The need for comprehensive planning and analysis has been understood for more than a century. Today, GIS technology provides the capability to analyze, dissect, and plan for fire protection problems quicker and with greater detail than previously possible.

Sir Eyre Massey Shaw, London Fire Brigade, authored *A Complete Manual of the Organization, Machinery, Discipline, and General Working of the Fire Brigade of London* (Layton 1876), which states, "If you wish to control a problem, you must know more about the problem than anyone else, and if you need to know more about the problem, you must coin a terminology, a lexicon, that allows you to understand it and not use imperial rhetoric."

In 1876, the London Fire Brigade was already developing fire preplans for buildings.

GIS can help define station locations; realign response districts; and identify and better understand hazardous materials locations, industrial facilities, commercial occupancies, water supply locations, and high calls-for-service areas. The goal of fire protection planning is to improve fire departments' level of service. Establishing standards and expectations for fire protection is essential.

Standards of Cover Planning

Standards of cover goals are established to identify risks and needs for desired fire protection. These deployment goals are based on community risk and community expectations should an emergency occur.

GIS is a powerful tool in establishing a comprehensive systems approach for analyzing deployment and assessing a department's current deployment efficiency.

The standard of cover process has nine parts.

- Existing deployment—Assessing the department's current deployment configuration and capability. Included in the assessment is a review of the historical decision-making process of the agency. Is there a reason stations are in their present locations? What equipment has been purchased and why? Can these past decisions be changed?

- Community outcome expectations—What are the current community expectations for fire protection and emergency service delivery? Included in this outcome is a review of response anticipated for the variety of fire risks in the community, emergency medical services (EMS), heavy rescue, hazardous materials, human-made and natural disasters, aircraft and airport, and water and shipboard incidents.

- Community risk assessment—What assets within the community are at risk? For example, structure fire risk might be assessed using fire and life safety factors, such as fire flow and code compliance, to determine a risk classification. Risk classes

might include low, moderate, and maximum risk. Many communities may conclude a majority of areas identified as moderate, or typical risks, are composed of dwelling units. In addition, different responses may be provided to urban, suburban, rural, or remote areas as defined using census terminology.

- Distribution study—Where are locations of first-due resources?

- Concentration study—Where are the concentrations of incidents and the adequacy of the first alarm assignment or effective response force?

- Historical reliability—Is there a multiple-call frequency issue such as call-stacking simultaneous calls within a specific area or areas?

- Historical response effectiveness studies—What percentage of compliance does the existing system deliver based on current performance goals?

- Prevention and mitigation—Are there tactics that can be initiated to strategically impact the outcome of events that do occur? The United Kingdom released *The National Plan* in 2004, which replaced earlier standards of coverage documents. The new report found that, without prevention and mitigation, impacts on the level of safety for responders and the public would reach a plateau. Using analysis of risk and looking at what strategic actions can be taken may not only prevent the incident from occurring but may also minimize the severity when and if the incident ever occurs.

- Overall evaluation—Propose standard of cover statements by risk type; for example, "In 90 percent of all incidents, the first-due unit shall arrive within four minutes' travel or six minutes' total reflex time. The first-due unit shall be capable of advancing the first line for fire control or starting rescue or providing basic life support for medical incidents."

  Another example might be, "In a moderate risk area, an initial effective response force shall arrive within eight minutes' travel or ten minutes' total reflex time, 90 percent of the time, and be able to provide 1,500 gallons per minute for firefighting or be able to handle a five-patient emergency medical incident."

GIS can be used to determine if proposed coverage statements may be impacted by events occurring outside the control of the agency. In other words, what will be affected if roadways are closed due to trees or other blockages? Can the response still occur? Alternate plans may have to be developed for risks based on the data generated through GIS analysis.

GIS can also be used to evaluate if the standards of coverage statements are being met and, if they are not, reveal when and where and what conditions are preventing meeting the standard of coverage. Based on the analysis, different station locations may be necessary or alternative means for delivery of service may have to be deployed. A tactic being used in some areas is positioning roving units for EMS based on historic call volumes during specific days and times.

Simply creating a coverage statement is not enough; analyzing whether the agency is in fact meeting that coverage is critical to maintaining the credibility of the organization. If the agency states it can provide a level of service, then does not, the safety of the responder and/or public may be at risk.

GIS provides fire personnel with a tool that integrates isolated data systems that can be effectively analyzed and displayed for a variety of planning and preparedness functions. GIS enables users to visualize and analyze all aspects of standards of coverage.

An effective use of GIS for planning requires

- Data
  - Street data with address points or address ranges
  - Water lines and hydrants placement
  - Utilities information for electric systems and gas main locations
  - Development services information on buildings and zoning information
  - Hazardous material and target hazard locations
  - Fire department information including fire station locations, historical incident reports, demand zones, and inspection records
- Software
  - Comprehensive GIS software with analysis capability including spatial analysis and network analysis
  - Geocoding tools and data editing capability
- Hardware
  - Computer hardware including a workstation with sufficient memory, storage, graphics, and processing capability to support comprehensive GIS software, printer, or plotter for map production
- People
  - Person or persons proficient in GIS technology to manage the fire department GIS projects and conduct appropriate analysis
- Methods
  - Important to identify exactly what is required and which GIS information analysis and products are required, since GIS technicians assisting the fire department may not be intimately familiar with requirements and overall responsibilities of the fire department mission

Examples of other functions GIS can perform for fire service planning and analysis functions include

- Display of jurisdictional boundaries including fire demand zones—GIS can display a theme (editable) with an underlying data table describing all the appropriate information for each demand zone and jurisdictional area.

- Layout of streets and local/state/federal highway network—GIS can display streets by type (streets are usually represented by a line). These streets are accompanied by a data table with address ranges. Events or incidents, hydrants, or other features can be added to the map display by entering an address. A point will be added along the street, which represents the address location. Response time analysis from fire station locations can be modeled along the street network to determine coverage for various response time requirements.

- Defining mutual and automatic aid zones—GIS can display a theme (editable) with an underlying table describing all the appropriate information for each mutual aid zone and/or automatic aid area.

- Definitions of geographic planning zones—GIS can display the various land-use areas, planning zones, or other regulated-use areas. These areas will contain tables with all the appropriate information.

- Locations of buildings and parcels—GIS can display all the parcels within a jurisdiction along with all the pertinent ownership records in an associated table for each property (property values, ownership, property tax, etc.). Building footprints can be displayed for each parcel. The appropriate information for each building can be contained in an associated table. Information and images, such as blueprint drawings, building values, and owners, can be associated with the building footprint on the GIS display.

- Topographic features—Topographic features can be displayed in GIS. This can include slope, vegetation aspect, soils, rivers, earthquake faults, erosion zones, floodplains, and so forth.

- Demographics—The demographics can be displayed by geographic area (block groups, ZIP Code areas, etc.). This would include income levels, ethnicity, age groups, and so forth.

- Incident trend analysis—GIS can display emergency responses by placing a point on the address or geographic area where it occurred. The underlying table contains associated information about each incident. By clicking on the point, information about the incident type, date and time, response units, damage, victims, and so forth, can be accessed.

- Displaying travel times along a road network—The user can identify a point (station location) and determine the shortest route to another location. GIS can also identify where a unit could travel within a specific time period from a station in any direction.

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- Display of pipeline systems—GIS can identify where a water system or network of pipes for petroleum or chemicals reside within a geographic area. The pipeline can display valves, mains, shutoffs, supply points, and so on. The underlying table can contain information about pipe size, materials, directions of flow, and so forth.

- Locations of built-in fire protection devices—GIS can display all buildings and facilities that contain fire protection systems and devices. The underlying table can contain the information concerning the protection system—contact person, number of devices, types of devices by location within the facility, and so forth.

- Locations of fully sprinklered buildings—GIS can display the buildings within a jurisdiction that contain sprinklers. Blueprints can be linked to the building footprint with a complete diagram of the sprinkler system. The user can easily access this information.

- Locations of standpipe-equipped buildings—GIS can display all buildings within a jurisdiction that contain standpipes. The user can display relevant information concerning standpipes including blueprints.

- Local fire alarm buildings—GIS can display all the alarm boxes or buildings with alarms within a jurisdiction. GIS can be linked to alarm systems and display the location of incoming alarm activation. Information about each alarm—exact location and more—can be contained in the underlying table.

- Display of risk occupancy—GIS can display the locations of all types of occupancy including worst or maximum, key or special, typical or routine, and remote or isolated along with other important information associated with each occupancy.

- Display of "hard to serve" areas—GIS can display all the areas that are difficult to serve due to one-way roads, long travel times, multiple addresses within a single building, or other complications. The underlying table could contain information describing why these areas are difficult to serve or actions to reduce service time delays.

- Hazardous materials point locations—GIS can display locations where hazardous materials are present. Each location can be color coded by degree of danger, and underlying tables can contain information about each hazardous material, safety precautions, and health hazards.

- Hazardous materials transportation corridors—GIS can display (on top of the road systems/railroads, etc., or other topographic features) where hazardous material transportation corridors exist. Pipelines that transport hazardous or toxic materials can also be identified along with valves, direction of flow, and so forth. Underlying tables can contain specific information concerning when transportation corridor risk is highest, common types of materials transported in each corridor, and so forth.

- Modeling—GIS can display a model (plume, explosion, flood, earthquake, epidemic, etc.). The model can be used with other GIS data to analyze infrastructure damage, road closure requirements, casualties, and other issues important for planning and response to potential or unfolding events.

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- High EMS demand area—GIS can conduct an analysis of historic EMS calls by geographic area. Those geographic areas with high call volume can be identified and compared to other important information—demographics, land use, and so forth—to determine possible relationships and mitigation strategies.

- Assessed valuation (by category)—GIS can display assessed valuation classified by geographic areas, color coded by valuation. Underlying tables could contain information concerning the assessment, values, ownership, land use, and more.

- Preplanned structure locations—GIS can identify structures by icon, color code, and so forth, where preplans exist. By clicking on the structure, all the preplan information for the desired structure can be displayed. Floor plans, specific preplan actions, contacts, shutoffs, hazardous materials, and so forth, can all be accessed.

- Fire prevention assignments—GIS can identify all the areas of specific fire prevention programs, compliance inspections, fire prevention inspectors assigned by areas, and the like. Underlying tables can identify specific program tasks, status of current program implementation, and so on.

- Arson/Unknown fire locations—GIS can display known or historical arson areas, areas with criteria that suggest arson potential, and so forth. Underlying tables might contain information concerning arson history, owners that have had multiple arson events, common arson devices, and the like. GIS can also identify known arsonist address locations, methods of operation, and arson history.

- Targeted occupancies for public education (by category)—GIS can display, by color coding or icons, properties with occupancy classifications that require particular fire prevention education programs. Underlying tables can identify what programs have been completed, ownership of properties, and so forth.

- EMS call demand by type—GIS can analyze and identify by area EMS call type and response time performance averages or response times for each call. Underlying tables can contain information about each EMS call: victim, date, time, and so forth.

- Evacuation zone planning—GIS can analyze evacuation routes from specific areas, ideal shelter locations, and other geographic information about evacuation routes and shelters including maximum amount of traffic flow and shelter capacity.

- Damage assessment modeling—GIS is ideal for conducting and displaying damage assessment related to disasters, fires, or complex emergencies. After assessments are conducted, GIS is able to determine the total damage or loss by value, property type, or other desired category.

- Emergency inventory resource location—GIS can identify and display emergency supply locations by supply needs, distance, travel times, airport access, and the like. Underlying tables can contain information about each emergency resource type—costs, handling procedures, and so forth.

- Support for communication/dispatch functions—GIS can identify where communication/dispatch backup locations exist, where mobile dispatch centers can be deployed with maximum communication coverage, and so forth.

- Display of external service agreement coverage area—GIS can display external service agreement area locations, classify them by type of agreement, and display other agencies that respond. Underlying tables can contain specific information about each service agreement area.

- Underground tanks—GIS can display underground tank locations, tanks with known seepage problems, and tanks that are abandoned or scheduled for removal.

- Critical care facilities—GIS can display key community facilities such as hospitals, schools, and blood banks. Underlying tables could contain specific information concerning hospital trauma capabilities, areas suitable for staging area implementation or incident command posts, and so on.

Response

First Responders

Lloyd Layman authored *Fire Fighting Tactics* in 1953 (first published in 1940 under the title *Fundamentals of Fire Fighting Tactics*) and developed the concept of "size-up." Size-up encompasses facts, probabilities, possibilities, plans of action, and so forth, for an incident. Layman writes, "If you are going to rush into an emergency, you better have your information together."

Firefighters and rescue workers, especially those involved with incident management, are well aware that the first few minutes of a call determine its outcome. A typical "room and contents fire" (the beginning of most house fires) reaches flashover within seven to ten minutes of ignition, and occupants who have not already escaped are not likely to survive. Likewise, a vehicle accident victim will begin to suffer brain damage if deprived of oxygen for more than six minutes.

The negative effect of lapsed time cannot be overestimated. As fire and EMS department services expand, the importance of GIS is becoming widely recognized. First responders must get to the emergency, size up the emergency, and deploy. The first responder's mission is to save lives and protect property and natural resources. Information that GIS can provide to support the first responder mission includes

- Incident location
- Quickest route
- Hydrant locations
- Preplans
- Photographs
- Floor plans
- Hazardous material locations
- Utility control points

Touch screen technology, coupled with mobile computer, allows first responders to access information quickly to reduce size-up time and results in quicker, safer deployment.

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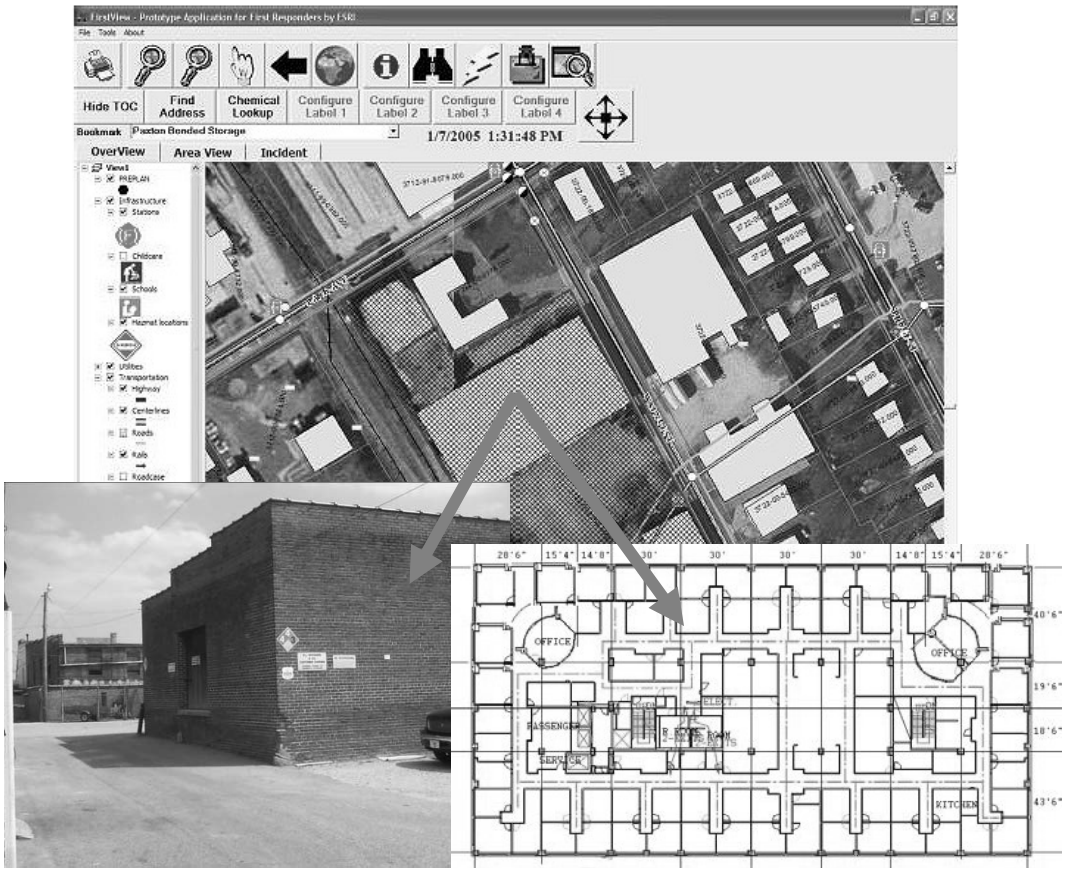
Figure 6



Tactical GIS applications provide first responders with information and data for more efficient size-up.

Chief Officers

When the chief officer or incident commander arrives at the emergency, he or she is responsible to manage the event rather than become part of the tactical deployment. The chief officer requires additional, different information to perform the command mission. Depending on the complexity and size of the incident, the information and data requirements may include the following:

- What other exposures or other facilities are threatened by this incident?
- Where should the incoming units be positioned to access hydrants and effectively support the units already on scene?
- If an equipment staging area or incident command post is required, where are parking lots, schools, churches, malls, or other suitable facilities located?
- If helicopter evacuation of victims is required, where are suitable landing sites?
- If medical triage or decontamination is required, where can it be implemented?

- If hazardous materials are involved or a chemical plume is being generated, where is it going, what does it threaten, and what actions are required to protect and evacuate the public?

- If an explosion is possible, who needs to be evacuated, and where is an immediate evacuation facility?

All these decisions require maps, data, and a variety of information from different sources. Having access to GIS data, including imagery, school locations, parking lots, adjacent exposures, and hydrant locations, provides an accurate picture of the event and supports critical command decisions.

GIS can meet the challenge of providing first responders and incident commanders with the right information, at the right time and place, that is easy to access and use. Much of the information first responders require has already been collected but resides in a variety of formats and locations. GIS can integrate the information, provide it graphically to first responders through intelligent maps, and allow the user to acquire other critical information. GIS can model explosions, plumes, and other potential emergencies. Instead of guessing or estimating evacuation requirements, transportation network problems, and other infrastructure threats, GIS will provide a more accurate prediction of the event and display the potential consequences.

Mobile GIS

As wireless broadband networks continue to expand, GIS support for a variety of operations becomes possible. Mobile PCs, computer tablets, and handheld devices with GPS and wireless advances allow first responders to send and receive geographic information and incident updates. For example, the city of Los Angeles Fire Department deploys a mobile computer with GPS in its command helicopter. Upon arrival at an incident (wildfires, floods, hazardous spills, explosions, etc.), the helicopter circles and collects and records a GPS polygon of the primary and secondary damage perimeter on the mobile computer map in the helicopter. These GPS perimeters can be wirelessly transmitted to a server. The perimeter polygons are combined with other GIS data on the server including imagery, streets, and block group census data. This Web-based GIS application is accessible by authorized Los Angeles city personnel. The GIS application posts the perimeter data and automatically generates a population effects report. Personnel from various departments, such as Public Works, Parks and Recreation, and Emergency Operations, can observe where an incident is occurring; zoom in to the imagery to visualize potential infrastructure damage and threats; understand how many people are affected, displaced, or injured; and determine possible evacuation requirements and shelter needs.

One of the most difficult tasks during the first hours of a large-scale emergency is collecting accurate assessment information. Mobile devices now make it possible for emergency personnel to record and add damage information to their maps and send this data to computers at the incident command post, Emergency Operations Center, or other unified command centers. This creates an integrated view of the incident that shows where the damage is most severe, affected critical infrastructure, and priorities for search and rescue.

In York County, South Carolina, the Fire Prevention Bureau created a database of routine flow and pressure tests conducted on fire hydrants. After soggy paperwork problems

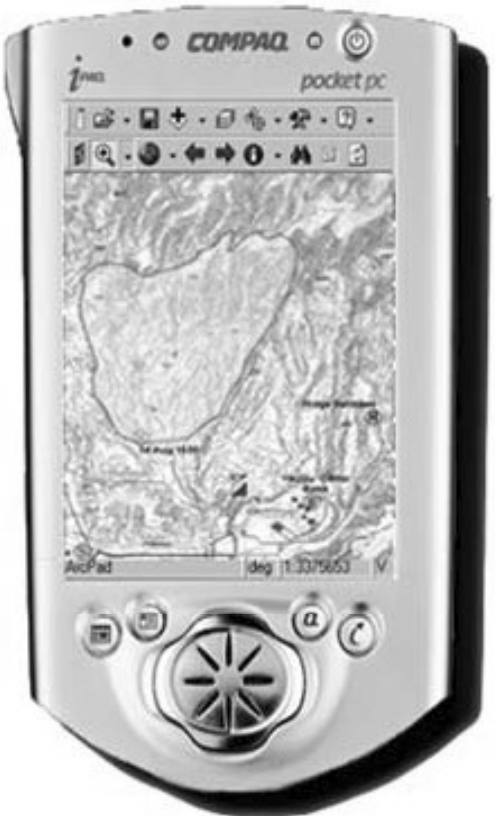
were experienced by field inspectors, handheld GPS-based units were programmed for point-and-click data collection.

The inspectors now perform more inspections each day because they no longer make frequent trips back to the office to hand copy notes. They accurately locate each hydrant, which enables GIS to map them, something never previously done. In York County, the hydrant map data is now available to anyone by logging on to York County's Web-accessible GIS. Firefighters will be able to consult a hydrant map before they depart for a fire, see where the closest hydrants are, and know which hydrants have failed recent pressure tests.

E-911 dispatchers have direct access to the fire hydrant status layer of the GIS in their computer-aided dispatch systems. A dispatcher can warn responding emergency crews if a hydrant near an emergency scene is not in service and direct them to the closest alternative.

Local insurance agents now consult the county GIS via the Internet to measure the distance between structures and hydrants without having to call county staff. This information helps them calculate more equitable fire insurance rates for property owners and provides greater efficiency for York County.

Figure 7



Incident perimeter mapping can be displayed using a handheld mobile device and GIS.

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Public Information

Providing the public with emergency information is an important component of emergency management. Historically, maps have been used as one of the key products for answering questions such as Where is the emergency? What is the status of the emergency? Which roads are closed? Which business facilities are closed? and Where are the evacuation centers? The press (TV, radio, print) has to understand the story before they can communicate effectively to their customers. GIS can be invaluable, providing fire information officers with maps that inform the press and allow them to focus on important issues. GIS maps can be filmed by television news to provide viewers with a better understanding of where the dramatic fire footage is occurring. Maps can be printed in papers and other print media and posted on Web sites to provide accurate public information. Another benefit is the ability for anxious homeowners who have been displaced to an evacuation center to view damage maps to determine if their property survived the disaster.

Emergency Management

During an emergency or crisis, maps play a critical role in responding to the event, search and rescue, mitigating further damage, and understanding the extent of the impacts. GIS is an appropriate platform to organize the extensive amount of spatial data both generated and utilized during an emergency event. A properly designed and implemented GIS will allow managers and responders to access critical location data in a timely manner so lives and property can be protected and restored.

Fire departments are the front line of defense for emergencies of all types. Large-scale emergencies range from natural disasters (earthquakes, floods, hurricanes, ice storms, etc.) to industrial or technological emergencies (e.g., train car derailments, petroleum fires, hazardous material spills) to terrorist attacks. Large-scale emergencies often involve multiple casualties, critical infrastructure damage, and evacuations and can last for several days or months. Managing large-scale emergencies is complex. Complex emergencies include search and rescue operations; displaced citizens; loss of utility services; and coordination among many departments, agencies, levels of government, and the private sector. One of the most complex challenges of emergency management is determining where damage is most extensive, where lives are most threatened, and where to assign limited emergency response personnel and equipment. During a major search operation for a lost or overdue hiker, GIS can accurately determine which sectors have been searched adequately and which sectors need to be revisited.

GIS provides a primary capability to organize, display, and analyze information for sound decision making. Using GIS data layers and imagery of the affected area(s), integrating damage and affected areas information, provides incident commanders with a comprehensive view of the emergency. In effect, GIS has the primary capability to create a common operating picture for the incident. Emergencies are very dynamic, and as circumstances change, GIS can reflect these changes. GIS can incorporate temporal information (weather, hazardous material locations, and emergency personnel locations) and model how an emergency might continue to evolve or what type of damage may be expected. These models could include

- Chemical plume dispersion
- Blast models
- Hurricane tracks and effects
- Flood damage

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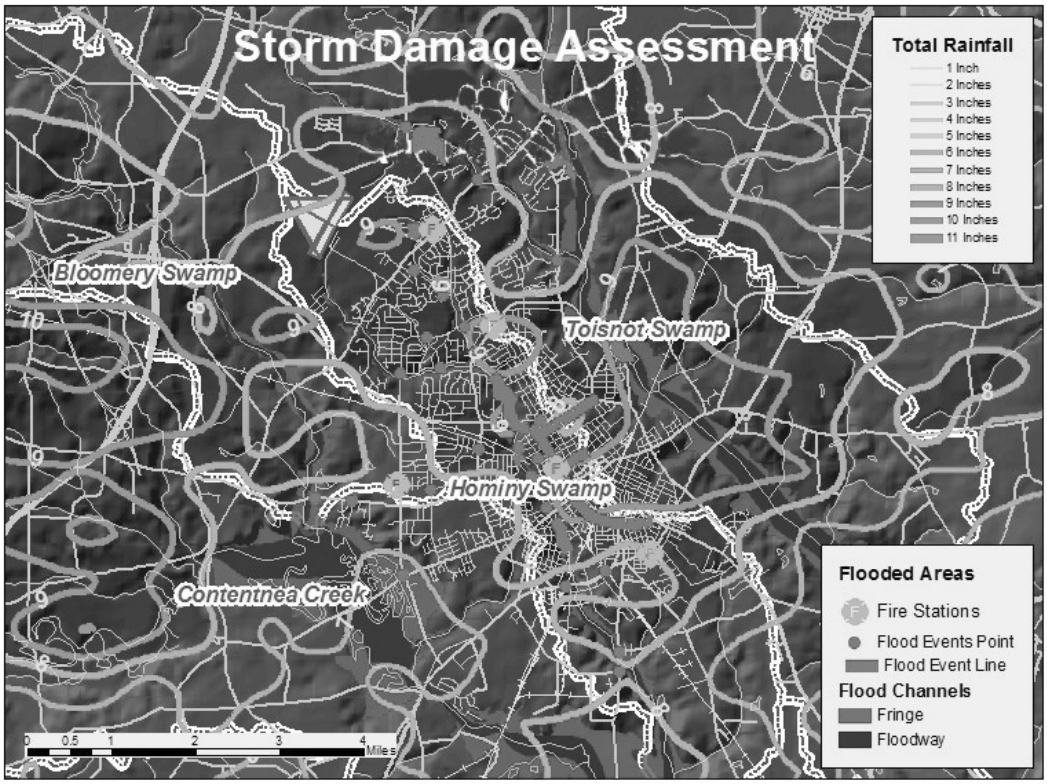
- Earthquake damage
- Wildfire spread

Models provide incident commanders a relative understanding of where evacuations may be necessary, potential damage to critical infrastructure, transportation network disruption, and so forth. Maps can be printed with the appropriate symbology to illustrate work assignments and incident facilities (incident command post helispots, staging areas, hot zones, etc.) and quickly dispersed to emergency personnel as part of the incident action plan. Areas with catastrophic damage are often confusing and disorienting to emergency personnel. GIS, with the appropriate data, provides a view of the area before the damage occurred, underground infrastructure, control points, potential hazardous material locations, and other information to support emergency response actions.

Figure 8



Damage assessment is displayed using GIS.

Wildfire

Wildfire planning and analysis, suppression methods, fire prevention and education, and vegetation management techniques continue to evolve and change through information management technologies. GIS is one of the primary technologies influencing these changes.

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Analysis and Planning

Analysis

GIS allows fire personnel to better view and understand physical features and the relationships that influence fire behavior, the likelihood of a fire to occur, and the potential consequences of fire events.

Hazard Identification

"Hazard" is the topography and vegetation on which a wildfire will burn. The identification and classification of hazard focus on understanding various topography types, vegetation types, and fire intensity expectations by individual landscapes.

GIS data requirements for understanding hazard include

- Digital elevation models—Digital elevation models provide users with the ability to extract information and data important for wildfire behavior such as
  - Slope—Steepness of slope
  - Aspect—Direction in which the slope faces (sun exposure and duration)
  - Contour lines—The ability to visualize terrain and elevation features
- Vegetation
  - Vegetation polygons by species type.
  - Vegetation grouped or classified by fire behavior models or characteristics (potential fire spread and fire intensity characteristics groupings). An example of fire behavior vegetation models used by wildfire agencies in the United States is shown in table 1.

Table 1

Fuel Model/Class	Model Description/Typical Complex
Grass and grass-dominated models	
1	Short grass (1 ft.)
2	Timber (grass and understory)
3	Tall grass (2.5+ ft.)
Chaparral and shrub fields	
4	High pocosin/chaparral (6+ ft.)
5	Brush (2 ft.)
6	Dormant brush, hardwood slash
7	Southern rough/low pocosin (2–6 ft.)
Timber litter	
8	Closed timber litter
9	Hardwood litter
10	Heavy timber litter and understory
Slash	
11	Light logging slash
12	Medium logging slash
13	Heavy logging slash
Nonfuel	
14	Water
15	Bare/Nonflammable

Example of Fire Behavior Vegetation Models Used by U.S. Wildfire Agencies

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- For fire behavior modeling, additional datasets may be required such as
  - Canopy cover
  - Stand height
  - Duff loading
  - Coarse woody vegetation
  - Gridded fire weather indexes

The result of hazard identification will be a GIS data layer that rates or classifies landscapes based on potential wildfire intensity under a given set of weather conditions. Landscapes can be assigned numerical values or given generalized descriptions such as extreme, high, medium, or low.

Risk Identification

The identification and classification of risk focuses on understanding historical fire ignitions, land use, and naturally ignited wildfires (lightning). The purpose of identifying risk is to classify landscapes based on the likelihood of wildfire ignitions. Classification of the severity of risk is based on the amount and variety of risks within a geographic area. The types of GIS data include

- Historical incident occurrence by incident type and location
- Land-use zoning
- Transportation corridors (roads, rail, off-road, etc.)
- Communities
- Recreation areas
- Industrial use

The result of the risk identification will be a GIS layer with risk polygons rated based on the density or accumulation of various risks within a concentrated area. Risk can be classified by numerical value or generalized descriptions such as

- Extreme
- High
- Moderate
- Low

Value Identification

Value identification focuses on identifying values and their tolerance (or intolerance) to wildfire. The purpose of value identification is to understand what type of fire protection actions will be necessary to protect or preserve them. The types of GIS data required to identify values can include

- Housing developments
- Recreation developments
- Sensitive or protected plant species
- Sensitive or protected animal habitat
- Commercial timber landscapes
- Cultural resources
- Other natural resource values

The result of the value identification will be a GIS layer with all the important values identified and displayed.

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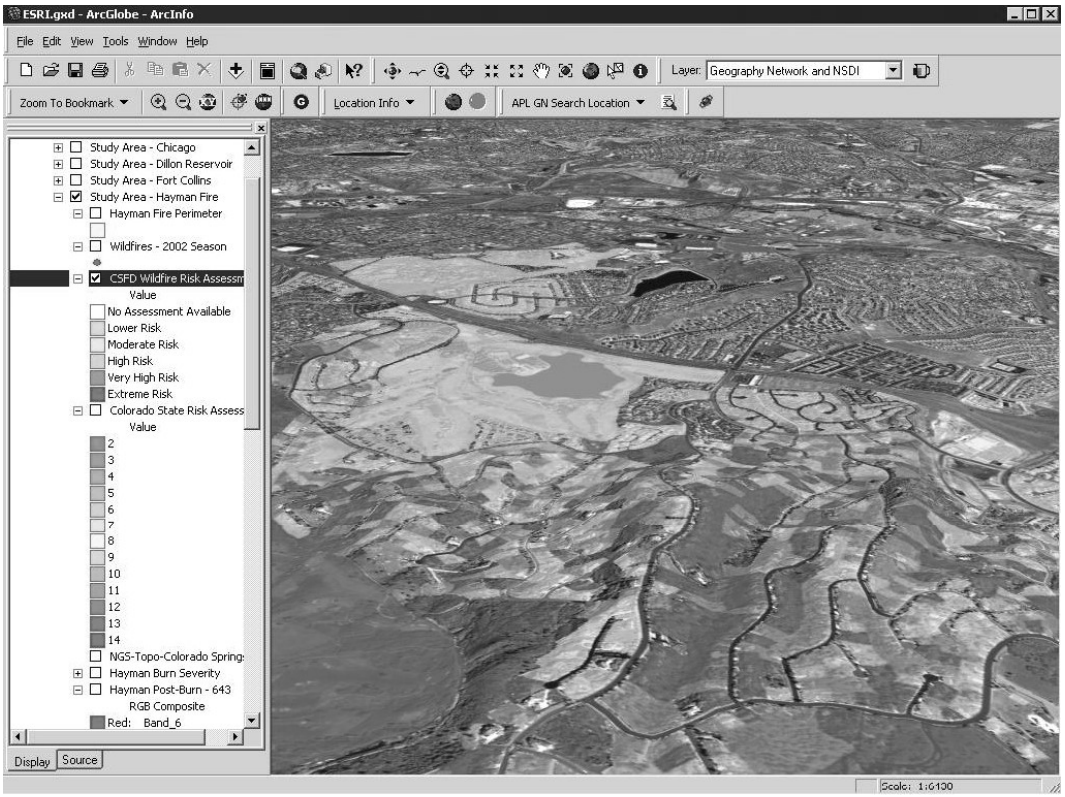
Figure 9



GIS illustrates fire hazard areas.

Aggregation

The last step in wildfire analysis is the aggregation of hazard, risk, and values. The result of aggregation will be a GIS layer of fire management landscapes with a fire behavior hazard rating (potential fire intensity), a risk rating (potential for fire ignition), and an inventory of values at risk. The aggregated fire management landscapes provide the foundation for a comprehensive wildfire protection plan.

Planning

Upon completion of the wildfire analysis, a comprehensive plan can be developed for each fire management landscape. The plan will identify priority fire prevention, vegetation management, wildfire detection, and wildfire suppression program needs based on the combination of hazard, risk, and values within each landscape. Wildfire programs are expensive, and it is critical they be implemented effectively. The appropriate mix of fire prevention, vegetation management, and suppression response capability can be prescribed based on the values at risk, the potential for wildfire ignition, and the projected wildfire intensity.

GIS for Fire Prevention

Wildfire prevention efforts can be focused where wildfires pose the greatest risk of resource loss. When intense fire areas (highly flammable landscapes) exist near high-risk areas (ignition sources) and high values, fire prevention becomes critical. Historical fire information can be viewed with all the other landscape information. Fire prevention officers can begin to determine an appropriate program strategy. This fire prevention strategy may be one of education, enforcement, or engineering, depending on the type of

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land use and historical fire causes. As housing development continues to expand and encroach into wooded and brush-covered areas, it becomes fire prone. The "urban interface" requires extensive fire prevention and fire protection measures. GIS can model and display potential fire prevention/protection strategies.

Figure 10

GIS models potential fire protection strategies for the wildland-urban interface.

GIS for Vegetation Management

Landscapes that require vegetation management treatments (e.g., prescribed fire, mechanical treatments) will stand out when using GIS. Landscapes with high flammability characteristics (high hazard, high risk, and high value) become obvious candidates for vegetation or fuel treatment programs. GIS technology allows fire managers to identify prescribed fire and vegetation management projects with the highest benefit (meeting multiple goals for resource and fire management). Vegetation management tactics can include mechanical, chemical, or prescribed burning techniques. GIS can assist in modeling how a fire will behave and spread under a variety of conditions to assist in developing fire prescriptions.

Fire Suppression

Maps are the foundation for fighting wildfires. They are used for communicating operational assignments and potential spread scenarios, providing a visual reference for incident team strategy discussion and conveying incident assignments to line personnel. Maps answer questions such as What is the topography in and near the fire? What is the jurisdiction(s) of the fire, and where is it likely to spread? Where can firefighters safely be deployed based on the topography, vegetation, and fire spread? Maps help managers

deploy resources safely and assess the potential overall damage of the fire. It is difficult to obtain detailed and comprehensive information from a paper map. Information is often gathered from maps, documents, and technical personnel over several days. Using GIS, this information is immediately available and can be easily viewed and understood under extremely stressful conditions. It is now common to see a GIS team assigned within the planning section of an incident management team. GIS teams provide maps showing transportation routes, facilities, air hazards, spread prediction, operations, and other geographically related incident management information.

Incident commanders want accurate information and intelligence before making tactical decisions. Historically, information has often been gathered through the use of paper maps, on-scene resource advisors, and observations from the air and the ground. Maps are the foundation for fighting wildfires, particularly large fires. Maps are used for communicating operational assignments and potential spread scenarios and for providing a visual reference for incident team strategy discussion.

Laptop computers now have the storage, performance, screen brightness, and strength to be used in the field. It is possible to have a great deal of information in a laptop computer. It is now possible to have hundreds of maps, images, and detailed information in the fire manager's vehicle and at the incident command post in the initial stages of a wildfire. First-response helicopters can capture the perimeter using GPS and wirelessly transmit it to operations personnel on the ground. Command decisions, such as placement of firefighters, suppression protection priorities, and potential evacuations, become more effective with accurate information. Incident Action Plan maps can be printed from the vehicle on a small printer or can be remotely transmitted to the dispatch center, multiple agency command centers, and national headquarters. Decisions concerning how to manage the wildfire (tactics and strategy), resources at risk, firefighter safety, resource protection priorities, and so forth, can be determined quickly and efficiently with the assistance of GIS tools.

The United States Department of Agriculture Forest Service commissioned a study to evaluate the use of GIS for large wildfires. The published document *Study of Potential Benefits of Geographic Information Systems for Large Fire Incident Management* (Fox & Hardwick 1999) includes project findings as follows:

> The participants in this study [members of incident command teams based in California including individuals employed by federal and local government agencies] overwhelmingly agreed that GIS would be a useful tool for large fire management. It would be a complement to existing tools, providing information that is not available now, and allowing certain information to be gathered in a more timely or cost-effective manner than it can currently be collected. They believed GIS would put accurate information in the hands of those who need it, when and where they need it. Better information leads to better decision making, which in turn leads to fighting a fire more effectively, efficiently, and safely. It will also facilitate the public information portion of fire management, freeing valuable resources for other efforts.

The publication identified the following tangible benefits of GIS use for wildfires:

- Saving money by not performing unnecessary tasks ($2 million during the Palm Fire, 1997)
- Improving safety by accurately identifying hazardous areas
- Improving crew confidence in management decisions by confirming human observations with hard data
- Saving time by reducing the extent of physical reconnaissance efforts

Education and Training

GIS is beneficial for education and training. Wildfire management personnel require several years of experience and training to become proficient. GIS provides access to detailed landscape information during wildfire events. Fire personnel begin to understand the complexities, fire effects, and fire behavior characteristics of various wildfires much sooner when using GIS. Modeling provides a better understanding of what a fire might do and what elements influence the wildfire most. Wildfire knowledge has traditionally been gained through years of experience, formal training, and discussions with experienced fire personnel. GIS is now another resource fire personnel can use to expand their understanding of the variables and complexities that affect wildfires. As modeling becomes more precise, dispatchers will be able to determine the potential of new starts and possible dispatch requirements.

GIS is a vital tool for wildfire information management. GIS is a primary repository of information that can be quickly accessed and viewed when required. GIS is becoming more suitable for emergency field operation use and is integrating tools that allow real-time display of information. Rapid access to information, safety, efficiency, and better resource management decisions are being made with the use of GIS for wildfire management. Information is critical for wildland fire management. GIS is information, all in one place, easy to visualize and understand.

Summary

The fire service mission is to protect life and property from fire and other natural or man-made emergencies through planning and preparedness, incident response, public education, and code enforcement. To accomplish this mission, GIS is rapidly becoming an essential tool to analyze, define, clarify, and visualize community fire problems in the development and execution of fire protection policy. GIS can model a community or landscape; analyze and display features important to the fire service mission; and provide access to important documents, photographs, drawings, data tables, and so forth, associated with features on the GIS map display. GIS can analyze and measure response time capabilities; identify incident hot spots by time and day of week; and target hazards, hydrants, and other information important for deployment analysis. First responders can have immediate access to critical information for emergency incident locations or best route and detailed information concerning the building or facility to which they are responding. Incident commanders can maintain better scene control with detailed maps and imagery of the emergency location as well as the exposures and features around the incident. GIS is essential for the management of large-scale emergencies or disasters where large numbers of public safety resources are deployed, with various resource assignments during a dynamic incident. Resource status, event prediction, incident facility identification, public information dissemination, and incident status are all more effectively and efficiently performed using GIS.

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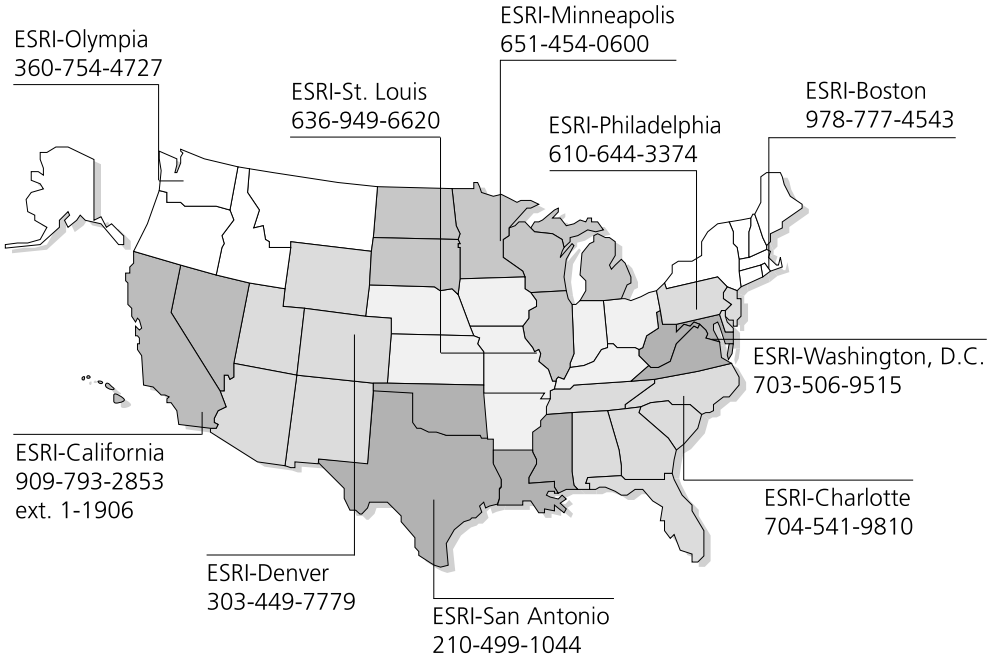

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