# GIS IN THE WORLD TRADE CENTER RESPONSE: 10 YEARS AFTER

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**ABSTRACT:**

The World Trade Center attack of 9/11/01 and the response brought major attention to GIS as a valuable tool for supporting emergency management and response. That attention led to the allocation of considerable resources to the enhancement of GIS. This paper is intended to provide a look back at the events prior to and immediately following the attack, review of GIS in the response and recovery efforts, explore the emergence of GIS in Emergency Management from the impetus generated in the NYC experience and explore the challenges yet facing the use of GIS in emergency management. The author participated in the WTC response as a member of the Emergency Mapping and Data Center component of the Emergency Operations Center through which the response was managed.

## 1. INTRODUCTION

The attack on the World Trade Center (WTC) in New York City (NYC) on September 11, 2001 had a dramatic effect on the world in many ways, and on the GIS field in very particular ways. The terrorist events demonstrated in unmistakable ways the value and utility of GI Science in emergency management. As has been noted elsewhere (e.g. Cahan and Ball 2002, Thomas et al. 2002, Bruzewicz 2003), the use of GIS was extensive during the initial rescue and relief operations.

GIS was reaching a level of maturity in the City at that moment and the City's GIS resources were applied fully to the emergency response. In fact, GIS emerged as a significant component of the emergency response and achieved national and international recognition for the contributions made in supporting the response effort. The events of 9/11/2001 and the months following saw GIS become recognized and emerge as a major contributor to emergency management as numerous breakthroughs and successes were achieved in what was, up until then, a nascent role for GIS in the emergency management field.

The events had a significant impact on GIS in EM in NYC and across the world. Consciousness was raised, the value of GIS was proven, numerous lessons were learned and documented, funds and resources were allocated and a wide range of development activities were undertaken.

### GIS Role Use and Value in Emergencies

The event exposed and promoted the value and usefulness to the emergency management community of presentation of information in a visual/map format. "A picture is worth a thousand words" is often quoted in justification of GIS. This concept is especially significant in emergency response in which time is extremely critical and numerous factors must be considered. A map provides a quick grasp and understanding of a situation, targets special issues (hot spots, outliers) and provides the means to quickly evaluate those.

In addition to the power of a map, the value of GIS as an information integrator, able to bring diverse data together, organized on the basis of location, was presented,. a capability that exposed many, heretofore unrecognized patterns and relationships. The importance and value of access to operational, regularly updated, up-to-date data to decision making for emergency response was validated.

The event also exposed shortcomings in GIS at that time as employed in emergency response such as limited capability for real-time data acquisition and management for the changing conditions in an emergency, reliance on plotting paper maps (dramatically slower than digital display and requiring plotting equipment that is mechanical and subject to breakdown), dependence on experts in the operation of GIS, almost all of whom were not emergency personnel or assigned to an emergency organization. The World Trade Center (WTC) response was forced to rely on contractors and a call to the GIS community for volunteers.

Why does GIS in the 9/11 WTC response have any relevance to us today, 10 years later? Because: GIS in Emergency Management (EM) was almost unknown prior to that moment. The attack was such a monumentally shocking event that most of the world was watching what happened at the WTC and, as GIS became a significant part of that response, the world's emergency managers became aware of GIS. CNN and other media outlets showed the colorful maps from the Emergency Management Data Center (EMDC) in their nightly reporting of events from New York. The interest thus generated in that experience promoted and energized the use of GIS in EM at a level that would have taken several years to develop under normal circumstances. And, in the US in particular, tremendous resources were then allocated to EM and a significant part of those resources were allocated to the technology that had proven so useful – GIS! And so today we have dramatically improved GIS capabilities in general and in EM in particular thanks in a large part to the experiences of that event.

Some of the best minds in the business were drawn to the development of improvements in technology, data and processes for GIS applied to EM. Fundamental concepts of GIS in EM were developed in the "trial by fire" of the WTC response that provide the basis for continuing research and development.

## 2 BACKGROUND ON GIS IN NYC PRIOR TO 9/11/01

A few specific actions taken in the period immediately prior to the 9/11 attack proved very significant to the emergence of GIS in the response. Those were:

- Creation of the NYC GIS Utility,
- Office of Emergency Management (OEM) GIS analysis, strategic plan & implementation
- Selection of the GIS Utility to manage GIS operations during the WTC response

### 2.1 Creation of the Citywide GIS Utility

As GIS had proliferated in many departments throughout the New York City Government it became apparent that there was a need for a central GIS service to create and maintain base data and provide resources and support services to the City's operating departments. An analysis was conducted in 2000 that resulted in the design and implementation plan for a GIS Utility within the Department of Information Technology and Telecommunications (DOITT), the City's central technical organization. The GIS Utility embarked on the establishment of a central repository for a comprehensive array of base, function specific and administrative data, the compilation of which was nearly complete by 9/11/01. That database consisted of dozens of **"**layers**"** of map data and associated attribute data. The central repository was established with adequate server capacity for the database and applications to support acquisition, Quality Assurance (QA) and distribution of data from and to participating departments and related organizations.

At the time of the attack, the GIS Utility in development in NYC was one of the more advanced GIS implementations in the country, built around the then state-of-the-art concepts, including an eGovernment emergency web site, server and Relational Data Base Management System (RDBMS) data management and other en-vogue technologies and practices.

### 2.2 OEM GIS Analysis, Strategic Plan & Implementation

One of the services provided by the Utility was assistance to departments and agencies in implementing and enhancing GIS capabilities. One of the agencies that drew on that service was the Office of Emergency Management (OEM), which was (and is) responsible for emergency preparedness and response throughout the City. OEM had been employing GIS tools in a limited and ad hoc manner, and recognized the need for a comprehensive approach to GIS and its incorporation into the workflow of emergency operations. And so, prior to 9/11 a Strategic Plan had been developed and was in the process of being implemented. The plan raised the consciousness of OEM managers and personnel regarding the effective use of GIS in their operations. The Plan included extensive use of the GIS Utility data and resources as well as OEM's own emergency specific data. The Plan identified GIS data, system architecture and a suite of applications required for use in OEM operations.

### 2.3 Selection of the GIS Utility to Manage GIS During the WTC Response

Unfortunately the City's Emergency Operations Center (EOC) was located in Building WTC 7, which had to be evacuated shortly after the initial attack. As the EOC was reconstituted following the loss of the primary EOC, responsibility for GIS and map support was assigned to the GIS Utility. The OEM GIS capabilities, still in development at that time, were merged into the EMDC under the direction of the GIS Utility Manager. The selection of the manager for the GIS Utility also proved fortuitous. As the events of 9/11 and the resulting response period played out, Alan Leidner, the Utility Manager, proved to be a person of vision, energy, creativity and management ability. From the earliest moments after the attack, Mr. Leidner rose to the challenges of loss of both the EOC and the primary GIS Utility facility, the overwhelming demand for GIS services and the need to reconstitute an effectively operating service in the face of the chaotic situation of the first few days. This confirmed the belief that human leadership, control and management are critical to successful use of technology.

These three factors provided the basis for the effectiveness of the EMDC and proved to be instrumental in the dramatic success of GIS and emergence in the recognition of the value of GIS for emergency management.

## 3 WORLD TRADE CENTER EMERGENCY RESPONSE

### 3.1 Immediate Post-Event Period

At 9AM on September 11, 2001 the twin towers of the World Trade Center in New York were destroyed by a terrorist attack that cost the lives of 3,000 people and caused several billion of dollars in damage. The full resources of the City's emergency and public safety resources were called into action in a massive response effort that extended for over 6 months.

A key issue challenging the use of GIS in the initial response period was the fact that the building in which the City's EOC was housed, WTC 7, became engulfed in the fire and had to be evacuated almost immediately after the attack. And the building housing the GIS Utility, 75 Park Place, 2 blocks from the WTC site, was also evacuated and closed, making most of the GIS Utility resources unavailable. The story of the immediate re-creation of the necessary capabilities and data is dramatic.

A brief summary of the actions includes acquisition of backup data from the Utility's QA operations at Hunter College, the "borrowing" of hardware and software from the Parks Department among others, and the immediate staffing with personnel from a few city departments and personnel from the contractor assisting in the development of the GIS Utility and OEM GIS.

The City established an immediate temporary EOC in the Police Training Academy on 20th Street. The EMDC was initially constituted in that building and began generating maps to support decision making by Mayor Giuliani, OEM, and the police and fire commanders.

After three days of operating in a temporary location in the New York Police Department (NYPD) Training Academy, the EOC & EMDC moved to Pier 92 on the Hudson River.

The EMDC area of the EOC was supplied with new hardware and GIS software; and the data was quickly loaded from the data sets used in the Police Academy. Very quickly the EMDC went into operation generating maps and reports for the decision makers in the EOC and the commanders and responders at the WTC site, which became "The Pile" in common usage reflecting the reality of the "pile" of steel, concrete and debris several stories high at the location of the destroyed buildings.

### 3.2 Operations on the "Pier"

Since GIS had not been widely used previously in emergency responses, early activities in the EMDC focused on education of

the customers, establishment of the GIS workflow process, of the availability of the EMDC, its resources and products, communicating with customers to define specific products, creation of sample map sets to facilitate specification of request orders, development of services for the wide range of customers and initiation of 24/7 operations.

Numerous unique GIS applications and maps, some useful some not so useful, were produced in the EMDC. For example, lidar elevation data for the pile was used to calculate the amount of debris to be removed. 3D maps, color coded by elevation, were produced from that data also. Color-coded maps of active fires were generated from thermal imagery but these maps were not of sufficient detail for use by the Fire Department of New York (FDNY). Fires continued to be active for over a month. GPS proved to be of limited value for measuring location due to precision problems (variable from .5 to 200m) caused by interference from the steel structures around the site.

Digital photographs of the impact site and vicinity were obtained by the Fire Department Phoenix, Photography and Imagery Group, by holding a digital camera out of the window of a police helicopter. (Huyck & Adams).

Mr. Leidner, the EMDC Manager noted that: "Dealing with emergency-generated information in a large-scale disaster, because it's in constant flux, is a gigantic generator of new information that needs to be captured, communicated rapidly, integrated into existing "before" data and analyzed. Trained emergency data collectors such as Federal Emergency Management Agency (FEMA) Urban Search And Rescue (USAR) personnel and teams of local responders, inspectors and engineers along with remote sensors and aerial photography will be employed to produce information on a daily or real-time basis to support and guide emergency operations and decision making. Reliable and robust two-way transmission of information between the disaster site and the central command center must be established. (Leidner 2005)

The rescue and recovery operation led by the Fire Department, Police Department, Office of Emergency Management (OEM) and Port Authority (and supported by every other city agency) was a miracle of ingenuity, collaboration and hard work under dangerous conditions and a constant sense of threat. And during recovery operations, the city was hit by an outbreak of anthrax in midtown Manhattan and suffered a fatal airplane crash in Far Rockaway. (Leidner 2005)

## 4 POST-EVENT GIS DEVELOPMENTS

### 4.1 US Government Developments

Prompted by the events of 9/11/01, the US government created the new Department of Homeland Security (DHS) to cope with terrorism as well as to carry out emergency management responsibilities in response to the attacks of 9/11/2001. Since its inception DHS has provided significant funding for GIS developments in the field of emergency management as well as national security. Within the DHS a Geospatial Chief Information Officer (CIO) program was established, including a staffing unit led by the top level CIO position. Specific developments undertaken by DHS include improvements in information interoperability among emergency organizations, a DHS Geospatial Data Model, development of the Common Operating Picture (COP) concept and implementing technologies, acquisition and development of geospatial data on critical infrastructure, improved imagery acquisition and processing, and integration of GIS with related emergency systems.

### 4.3 World Developments

The response to the events of 9/11/01 energized Emergency Management and GIS throughout much of the world with a resulting dramatic increase in interest in geospatial capabilities, and expansion of R&D for location-centric emergency management tools and methods. A response similar to that of the US has occurred in many nations throughout the world, resulting in generated major focus on EM in general and GIS in particular. Government organizations and programs have been established providing funding for government and university research and GIS implementation has grown.

## 5 GENERAL GIS DEVELOPMENTS

The following section provides a summary of important experiences and lessons from the WTC response and the developments that have taken place since.

Major improvements in GIS and its use in EM have occurred in the ten years since the WTC event. Some of these grew out of the increase in support for IT and GIS following 9/11/01. Most were due at least in part by this interest. Their application to Emergency Management in particular was heavily stimulated by the interest generated in the experiences with GIS support for the 9/11 response and the heightened awareness that it brought for the needs and opportunities of greatly enhanced GIS use in emergency events.

Many of the advances can be specifically attributed to the 9/11/01. Dramatic advances were made in the fields of interoperability, remote sensing and satellite imagery, mobile technologies and applications, database concepts and data standards, and the application of geo-based capabilities to intelligence analysis.

The attack raised grave concern for antiterrorism that increased interest and funding for GIS as an intelligence tool beyond conventional emergency management. Due to the terrorist nature of the 9/11/01 attack, security has become a major issue and thus an important component of evolving systems. The author certainly doesn't wish to claim all advances in GIS use for EM resulted from the WTC experience. The parallel dramatic evolution from limited GPS use to the ubiquitous navigation devices, Google Earth, iPad and Smartphone applications goes well beyond any influence from the WTC experiences.

### 5.1 Topic: GIS Role in Emergency Response

**WTC Experience/issues:**

Though the capabilities and range of data were very limited by today's standards the event produced significant breakthroughs in demonstrating the value and the roles of GIS in emergency response. The EMDC also provided a "test bed" of GIS within emergency management operations. The capability limits to be overcome to greatly extend GIS role were also exposed.

**GIS Developments Since 9/11/01:**

GIS has become an essential component in most emergency management operations in jurisdictions of most sizes. In a growing number of cases a GIS centric approach has been taken to emergency management and use of technology. GIS capabil-

ity for displaying combinations of data, presenting spatial relationships, and integrating useful data and data from multiple emergency management systems on the basis of location have offered significant improvements to emergency management operations. The growth in the availability of geospatial data and increasing inclusion of a location key in data of all types have greatly increased the use and value of GIS to emergency response. An important aspect of the development is the availability of numerous easily used applications for direct GIS operation by all emergency personnel.

**5.2 Topic: Interoperability**

**WTC Experience/issues:**

The need to deliver information and maps to managers and responders from multiple sources exposed many issues such as authorization, transfer mechanisms and, most notably, incompatibility among source data and systems. The EMDC expended large amounts of time and resources on acquiring data and overcoming incompatibilities between sources and not all potentially useful data could be integrated due to incompatibility.

**GIS Developments Since 9/11/01:**

Interoperability and data sharing and exchange became a particularly high priority target for GIS development and improvement. Various approaches and solutions have been explored, among them are establishment of data exchange hubs through which data can be routed for transformation and standardization, Enterprise Service Bus (ESB) software-based implementation of the Service Oriented Architecture (SOA) concept in which a messaging system routes data through a series of transformations, security validations, and other processes from source to consumer and deployment of web server and web services for publishing and consuming data. The emergence of standards such as xml, GML, KML, HTML and others has facilitated interoperability as well. Business processes for managing and controlling the sharing of data also play an essential role in successful interoperability.

**5.3 Topic: Access to GIS Data & Functions in the Field**

**WTC Experience/issues:**

Since field access to GIS was extremely limited in the WTC response, it was necessary to plot paper maps and establish resource-consuming, inefficient logistics for delivery or pick up from field. These constraints led to limited availability of appropriate maps, delays in delivery, vulnerability of mapper maps for use in the field, and products that not always met the needs of each customer.
The need for mobile hardened, compact, light, devices capable of GIS applications operating on wireless communication devices was recognized and tests using available early mobile devices were conducted and evaluated. Such devices were not widely available in the field but envisioned in EMDC.

**GIS Developments Since 9/11/01:**

In NYC and many other jurisdictions handheld, wireless devices, some equipped with GPS receivers and portions of the city's basemap, are being provided to field workers. Daily use of these technologies will increase the productivity of city employees by 25 percent or more, and it guarantees their effective use during an emergency.

Another development is the provision of GIS capabilities in mobile command post vehicles in many jurisdictions. As an example NYC OEM has a mobile data center (MDC)--a bus-sized vehicle with GIS workstations, plotters and telecommunications--that can be rapidly deployed to a disaster site. The MDC makes it possible for field data to be collected, assimilated and analyzed "on the spot." MDC data products, maps and assessments then can be immediately provided to first responders without delay.

**5.4 Topic: Collaboration**

**WTC Experience/issues:**

The EMDC generated maps to facilitate discussion and decision making at collaboration meetings during the response. EMDC personnel participated in, observed and learned about the frequent, urgent collaboration that takes place during an emergency. These meetings involved a varying mix of people from multiple organizations requiring information support from a wide range of data. Through those experiences roles for GIS support for collaboration were identified and the improvements to capabilities needed were noted.

**GIS Developments Since 9/11/01:**

The lessons thus learned encouraged the GIS industry to find ways to support emergency collaboration with geospatial information and capabilities. That led to the definition of collaboration requirements and development of tools and processes that now support collaboration such as interoperability capabilities and the Common Operating Picture (COP).

Procedures and tools now allow flexible definition of communities of interest for collaboration to accommodate support for EOC wide, Emergency Support Function, organizational unit and other configurations of collaboration support.

**5.5 Topic: Common Operating Picture (COP)**

**WTC Experience/issues:**

As noted, collaboration is an essential activity in emergency response. Also observed in the WTC response was the fact that maps can play a vital role in collaboration. The EMDC generated maps to facilitate discussion and decision making at collaboration meetings during the response. However the use of paper maps in that response suffered from serious constraints. The production of numerous specially defined paper maps was time and resource consuming and at times not available when needed. It was recognized that the flexibility, interactive nature and easy distribution to all necessary workstations and large-screen EOC displays of digital maps could overcome the limitations and improve the value of GIS information, maps and processing for collaboration. A common set of information can be displayed simultaneously to all participants in a collaboration session regardless of their location.

**GIS Developments Since 9/11/01**

With the GIS and communications capabilities now available, the COP has become a widespread tool for emergency collaboration and decision making. DHS has sponsored. and commercial and governmental GIS developers have created COP capabilities at various levels of sophistication. Typically the COP draws on the capabilities of interoperability to access and integrate data from multiple sources and provides easily operated

applications to generate displays as needed by emergency persons directly. The COP enables collaboration among participants in an emergency response by providing situation awareness and the ability to interactively modify the information to address issues under discussion.

**5.6 Topic: Underground Conditions & Engineering Drawings**

**WTC Experience/issues:**

Below the WTC there were 5 levels of underground structure for vehicle parking, utility machinery, storage and other purposes. Below ground also were a critical rail tunnel arriving from below the Hudson River, a complex commuter rail and subway station and a shopping plaza. Very critical and dangerous activities were conducted during the response and recovery in these areas. Information sources for the below-ground structures were almost entirely plans and as-built drawings in hard copy. To support the underground activities, a major effort was required to convert at least some of the drawings into digital format and register them to the GIS maps of ground level. Again, GIS was recognized as a flexible and valuable information processing and display tool for this activity. While not a typical GIS application at that time, the GIS was employed as a data repository and manager for engineering, as-built and other interior drawings and a process was established to record and manage information and photography being captured by those working in those areas.

**GIS Developments Since 9/11/01:**

Since 9/11/01 most engineering drawings and as-builts are produced and stored digitally in CADD systems. Building Information Modeling BIM is becoming more widely used in the AEC industry. And, more recently dramatic advances have been made with its integration with GIS. Research is ongoing on the development of additional capabilities and uses for integrated GIS and BIM in emergency planning and response, including internal structure evacuation planning. Recent research in the field demonstrated that BIM can be used as the information source when transferring building information into the geospatial environment. (Isikdig & Zlatanova, 2008)

**5.7 Topic: 3D**

**WTC Experience/issues:**

3D capabilities for urban conditions such as those of lower Manhattan were not well developed in NYC at that time. Very little 3D building model data was available for the area and 3D software was not yet generally available in the City agencies. Some 3D scenes were plotted but their usefulness was very limited and response procedures at the time did not incorporate use of that technology.

3D potential was particularly recognized for supporting the underground operations and improved internal evacuation plans could have benefited from 3D data and visualization of halls, stairways and other internal evacuation routes and exits.

**GIS Developments Since 9/11/01:**

Considerable research is being conducted on various aspects of GIS for EM. An fundamental advance was made with the adoption of the City GML model as an OGC standard for 3D urban objects providing a base for development of visualization and other tools for 3D to facilitate understanding of an emergency situation. One area is improvement in Level of Detail (LOD) or Level of Realism (LoR) of features such as building facades. Research has been conducted on better and more efficient ways to collect the images and manage them in efficient ways (Bucholz & Dollner 2008). Another area of research is 3D navigation specifically for EM emergency response and evacuation planning including the integration of urban 3D models as part of a navigation system. The availability of an Open Source 3D engine has also facilitated further development of 3D tools for EM.

**5.8 Topic: Remote Sensing**

**WTC Experience/issues:**

Orthophotos in GIS Utility database were a few years old at the time of the attack. Since NYC is a mature city without much recent development activity, these orthophotos were useful for many purposes. Of course they did not show the post-attack situation and so new imagery was required. While SPOT imagery was acquired almost immediately, the level of detail was inadequate for most purposes; and so photogrammetric acquisition was necessary. The New York State Government OFT arranged for acquisition of new imagery. However the security concerns led to restrictions on the air space in the area and so special permission was required for flights. The contract process took several days for delivery of new post-event orthophotography. Re-flights were also carried out on a daily cycle. In addition to orthophotos, through the WTC experience the dynamically changing nature of emergency and need to acquire imagery rapidly and frequently with varying specifications and its significance to GIS use was clearly determined in the EMDC. Lidar data was also captured and used to calculate the volume of debris to be removed. Thermal imagery was acquired and used in an ad hoc manner to indicate the location and intensity of fire risks on the pile. The fires burned at high intensity for over a month. The experience and lessons learned in this ad hoc operation were used to validate the potential for this imagery and to indicate shortcomings and improvements needed, such as the level of detail required for operational use.

## 6 CHALLENGES REMAINING FOR ISS IN EMERGENCY MANAGEMENT

While the use and capabilities of GIS in EM have increased dramatically in the ten years since 9/11/01 to the point of being almost a different approach entirely to EM, there remain several challenges to continued improvement. Among those challenges the following remain from the WTC experience.

**Real-Time Data**

Improvements in real-time data acquisition and management such as those enabled by newly evolving technologies including mobile and wireless devices and the expanding use of social networking as emergency management tools pose new challenges for control and exploitation of the potential volume of unstructured data. These applications offer great potential for acquisition of real-time information from not only trained responders but also the public in general. However, the variance and disparity of data from the public has the potential for information overload and will require new methods for control and interpretation.

**Interoperability**

Challenges exist for improvement in interoperability, especially in the area of semantics. There are also needs for improvements in the methods and tools for delivery of high volumes of up to date data in actionable from and to field operations.

**Victim Tracking**

Discovery and tracking of injured, missing and deceased victims was an area in which the EMDC was able to provide little support. New technologies for identifying and tracking including affected persons (missing, injured, deceased) including their location are becoming available but there are yet challenges for effective use.

**Facility & Resource Vulnerability**

The immediate loss of the EOC and GIS facilities exposed the serious vulnerability of facilities and communications to the impacts of emergency events and the need to improve backup capabilities. Recovery capabilities including interoperability, and now, cloud computing offer potential new solutions to this challenge.

**Data Availability**

There remain challenges for the creation of pre-event data, especially for potential emergency impact areas that encompass multiple jurisdictions or authorities. The current approach is moving away from compilation of comprehensive databases incorporating all necessary data and toward the interoperability and web services approach in which access to original sources is provided through various combinations of software architecture, web services for publishing and consuming data and messaging and security mechanisms. Progress on interoperability and standards and standardization will facilitate data sharing.

**Actual Implementation**

A major challenge now is actually implementing GIS and its emergency capabilities within emergency operations including revision of operating procedures to reflect GIS use and training of emergency managers and responders in the use of GIS tools and products. More technologies are now available than are being widely or effectively used. While technologies and tools now available offer dramatic improvements in capabilities over those of 9/11/01, they must be imbedded in emergency operations prior to an event to be truly useful and this poses organizational, personnel and other challenges.

## 7 CONCLUSION

Although the attack on the WTC was a tragedy for the US, and in some ways for the world, it did give an important boost to the field of GIS for EM. GIS was employed extensively and successfully in the response to the attack and fortunately those experiences were well documented and publicized. The lessons from the experience provided guidance to subsequent research and development efforts.

The fact that the event and response were so widely publicized on the general media contributed to the dispersion of information that generated interest and support for further development of GIS in EM. A new Federal Agency was created in the US Government that provided funding and resources to further GIS development in this field.

The current state of GIS in EM differs dramatically from that of 9/11/01 and the advances that have occurred are due in part at least to the experiences and lessons of the response to the 9/11/01 attack on the WTC.

## REFERENCES

Cutter, S, GI Science, Disasters, and Emergency Management University of South Carolina, Transactions in GIS, 2003, 7(4): 439–445

Dawes, S, & Birkland, T, & Tayi, GK & Schneider, C , Information, Technology, and Coordination: Lessons from the World Trade Center Response, Center for Technology in Government, University at Albany, SUNY, 2004

DHS DATA MODEL: GEOSPATIAL MANAGEMENT OFFICE Issue Date: 11/12/2004, US Department of Homeland Security, 2004

Huyck, C, & Adams, B, Emergency Response in the Wake of the World Trade Center Attack: The Remote Sensing Perspective, *MCEER Special Report Series, Vol 3*, Long Beach, CA

Langhelm, R, 2002, WTC Chronology compiled By Ron Langhelm FEMA, 2002

Leidner, A,2005, Emergency Management Showcase, The Geospatial Response to 9/11, A Recount of Accomplishments and Unfinished Business, *GeoWorld*

Kevany, M, 2008, Improving Geo-information in Disaster Management Through Action on Lessons Learned from Major Events, in Zlatanova, S & Li, J (ed), *Geospatial Information Technology for Emergency Response*, London, Taylor & Francis Group

Kevany, M, 2005, Geo-Information For Disaster Management: Lessons from 9/11", in Van Oosterom, P & Zlatanova, S & Fendel, E, (ed), *Geo-Information for Disaster Management*, Springer Science + Business Media

Kevany, M, 2003, "GIS in the World Trade Center Attack", in *Computers, Environment and Urban Systems*, Elsevier

The 9-11 Commission, 2004, Final Report of the National Commission on Terrorist Attacks Upon the United States, Official Government Edition, US GPO July 2004