Curtis, Andrew, J. W. Mills, J. K. Blackburn, **J. Pine**, and B. Kennedy (2006). "Louisiana State University Geographic Information System Support of Hurricane Katrina Recovery Operations**."** ***International Journal of Mass Emergencies and Disasters**.* Vol. 24, No. 2. (ISSN: 0280-7270)
Published by **Research Committee on Disasters International Sociological Association**. The version of the record is available for open access at http://www.ijmed.org/articles/226/

Louisiana State University Geographic Information System Support of Hurricane Katrina Recovery Operations

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Abstract: During Hurricane Katrina a group of faculty, staff, and students at Louisiana State University voluntarily helped create, manage, and staff Geographic Information System (GIS) efforts in the Louisiana Emergency Operations Center (EOC). GIS is an integral component to decision support in all phases of emergency operations (Curtis et al 2006; Eichenbaum 2002; Gunes and Kovel 2000; Johnson and Uba 1997; Kaiser et al 2003; Kehrlein and Shreve 1995; Maniruzzaman et al 2001; Morrow 1999; Newsom and Matrani 1993; Pine 1997; Thomas et al 2002). However, for the Katrina response, no Louisiana state employees were assigned to the GIS desk at the EOC. This failure to have an established support system for all other agencies providing response could have been a devastating fault without the volunteer support provided by LSU. Most agencies looked for us in the EOC and then relied upon us throughout the operation. This paper documents the way our group utilized our academic backgrounds to expand and improve the geospatial decision support in the EOC.

Introduction

Even the most prepared Emergency Operation Center (EOC) is unlikely to have all the equipment, data, and skilled personnel to provide adequate geospatial decision support for response operations in the face of a disaster at the scale of Hurricane Katrina (Curtis et al 2006). Although the likelihood of the same type of disaster affecting other areas in the United States is obviously geographically limited, the forced evacuations of late August and early September in 2005 could be replicated elsewhere by a major terrorist attack. In order to provide adequate geospatial decision support for the massive response operation coordinated through the Louisiana EOC, various academic units from Louisiana State University (LSU) joined together to provide the infrastructure and expertise needed to cope with the disaster. This situation was exacerbated by a series of political events leading to no in-situ GIS presence in the EOC. This paper will describe the way in which our predominantly university based support group “grew” dayby-day both in terms of numbers and in operational effectiveness. The lessons learned will be presented as five central categories needed for geospatial decision support in an EOC.

A commonly taught concept, often stressed by FEMA, in disaster courses is that the local community must be able to react to a catastrophe for at least 72 hours before federal intervention. Although this concept is usually discussed independent of event scale, the basic premise is that for any natural or human caused disaster the local community must be able to understand, react and respond to unfolding events for the first three days after the disaster (CERT 2006). At the end of this period efforts can be supplemented or even replaced by federal intervention. Data and experiences can be “passed on” to the incoming teams.

For the majority of disasters this means that all response activities are coordinated and supported at the local level (CERT 2006). However, Hurricane Katrina showed that for a major catastrophe, the response period can extend into weeks after the initial impact. After the actual hurricane had made landfall, secondary events including levee breaks, flooding, looting, fires, shelter evacuation and finally city-wide evacuation meant that disaster response lasted for at least three weeks. During this time, the geospatial decision support team, coalesced from a variety of departments, computer labs and research units at LSU, continued to provide the majority mapping support to the EOC. The clientele had expanded from local rescue units to an assortment of teams from other states and federal agencies. Most of these groups accepted the volunteer round-the-clock presence as being a key support mechanism in the EOC. Indeed, it is likely that many units never knew the “GIS desk,” as it was called, comprised mainly of volunteers.

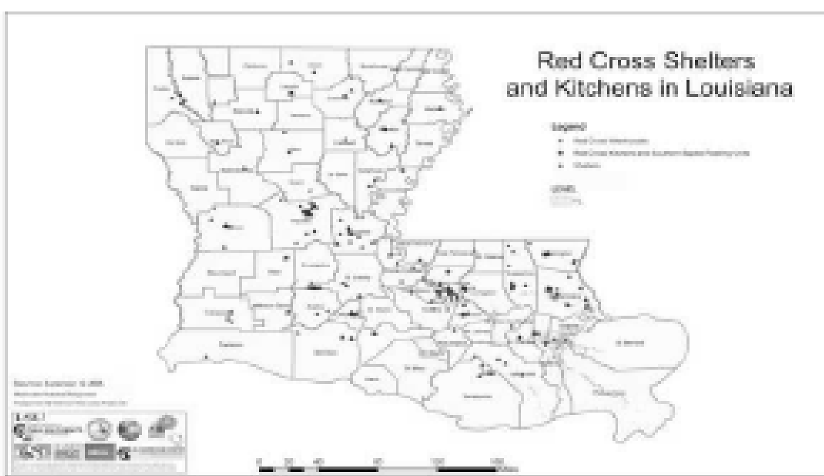
Unlike most other state EOCs, no existing geospatial decision support was present for Louisiana. This has resulted in a series of events and observations that will prove useful for major catastrophe planning in other states. The lack of an existing spatial support presence meant that there was little in the way of territoriality and adherence to set support practices. Although the response was not as efficient as it could have been due to the lack of such a set structure, this flexibility also allowed for a response system to evolve as needed. This evolution can now be used to provide insight and improvements in other existing EOC response strategies. Two incontrovertible facts have emerged from the response to Hurricane Katrina. First, no state EOC can provide total support for a catastrophe such as Hurricane Katrina, and therefore a flexible structure needs to be able to incorporate additional equipment, data and personnel as and when needed. A partnership with academia provides an obvious solution to this problem. Second, the response team and response strategy must be flexible as events will occur beyond existing preparedness strategies. It is therefore important to have spatial thinkers as well as spatial technicians as part of the response team. Again, a partnership with academia can easily fill that role.

Geospatial Decision Support in the EOC

An important part of the response to a major catastrophe is what could be called the creation of a “spatial knowledge hub”. The map is a vital tool for any coordinator or planner in the EOC, or responder in the field (Curtis et al. 2006; Eichenbaum 2002). The map plays many roles during the initial response; it can be used to identify route ways into and out of the affected area, it can help responders navigate into those areas, it can be used to plot the location of 911 calls, it can show where the deepest flooding is occurring, which roads are impassable and where clinics can be found. Obviously, the role of the map will change depending on the scale and type of disaster. For a tornado touchdown, requests for spatial information might be limited to a relatively small geographic area. For an event covering a larger geographic area, such as forest fire, the type of spatial request might be limited to events surrounding the actual hazard itself (pathways into the fire-affected area, properties likely to be affected, etc.). In a major regional catastrophe that results in mass evacuation, for example as in the case of Hurricane Katrina, requests can be incredibly varied and cover a large geographic area. Typical requests include making maps of flooded areas, generating road maps around levee breaks, 9-1-1 call locations, looter activity hotspots, clinic locations, and the location of state lands for temporary shelter locations (Figure 1). The role of the “GIS desk” in the EOC is to create these maps, in addition to providing any other spatial information such as coordinate locations as quickly and effectively as possible.

A geographic information system (GIS) is often the spatial technology used to create these maps. Simply put, the GIS is a spatial database that allows for multiple spatial datasets, ranging from street addresses to satellite imagery of flooded areas, to be combined in a single display. In this way, if an agency wanted to know where all 9-1-1 call locations were in one neighborhood, and whether that neighborhood had experienced any looter activity, and which roads leading into the neighborhood were flooded, the GIS could be used to combine these data layers using a common coordinate scheme. The answer to the request, or "product" as it was termed in the Louisiana EOC, would usually be one of three types.

Figure 1: Sample of Typical Geospatial Data Requests During Hurricane Katrina



First, large format (poster size) plots would allow the map to be viewed by a large group of responders or to a select group of decision makers. As a typical example of where these maps would be used, LSU graduate students working in the EOC would often be asked for daily update “posters” to be produced before 7:00 am to help brief visiting political figures, and be used in the early morning media update. Second, and in a similar vein, maps can be directly displayed from the PC, usually via a projection system onto the EOC wall, again as a tool to aid decision-making. Within the Louisiana EOC these images were continually projected along one wall. They could include news updates, the location of other weather systems across Louisiana, or the maps created by the EOC “GIS desk.” The flooded area overlay on a Google Earth 3-D image of New Orleans was a particular favorite within the EOC (Figure 2). Third, maps can be made for the response teams to take into the field. For example, a mini-atlas was designed and printed showing flooded areas on all city streets. This consisted of a citywide index with different city sections numbered on a grid. Each grid section would also be printed as an enlarged version. Each sheet was usually no more than legal size allowing for portability (Figure 3). In an ideal world this information could be passed on digitally to an onboard GIS/GPS unit within the response vehicle. However, in the event of a major catastrophe, the likelihood of all vehicles having this technology is unlikely. If no additional disaster related information, such as flooded areas, is needed, traditional printed PDF versions of city maps, or traditional city maps available in any bookstore or gas station, provide the best navigation tools.

A fourth type of spatial information request would not result in a map, but rather the locations would be extracted from a spatial source and relayed to the response team either verbally or as text. A typical example would be the extraction of coordinates from street addresses (9-1-1 calls) or coordinates from georegistered aerial photography displaying important building locations. During Hurricane Katrina, for example, a helicopter pilot would ask for coordinates of a series of clinics so a Public Health Service team could plan their assessment route.

Figure 2: Flooded Area Overlay on a Google Earth 3-D Image of New Orleans

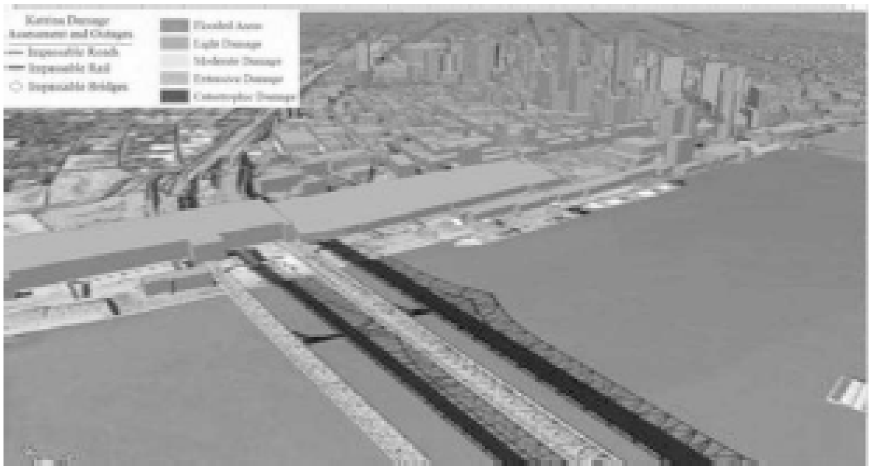


Figure 3: Mini-Atlas of Roads

For a catastrophe the size of Hurricane Katrina, the equipment, data and skilled expertise needed to create these cartographic products is likely to exceed traditional EOC resources. Requests for up to five posters would be made every hour at the height of the response; projecting maps on the EOC wall would tie-up one of the two computers running the GIS, each mini-atlas would require considerable time in initial design, and then further time in submitting print jobs, and finally the extraction of coordinates was labor intensive and time consuming. In addition, many of these tasks could not be completed if a background team didn't exist that could find the required data, could manipulate data, could process imagery and provide an overseer's eye on the entire process. The traditional structures of academic units mirror this required structure, with graduate students (and even undergraduates) providing the workforce, lab technicians and researchers providing the highlevel data collection and manipulation decisions, and research lab directors piecing together an evolving support structure that would encompass multiple units and locations.

As previously mentioned, the two aspects that would overwhelm the capabilities of any EOC facing a regional catastrophe would be the need for greater resources and the flexibility to evolve as the catastrophe unfurled. In order to fully examine these points and at the same time show how effective an academic liaison can be, geospatial response can be broken into five sub-categories: equipment, data, personnel, management system, and the “X” factor.

Equipment

Equipment needs are relatively simple for an efficient EOC spatial knowledge hub. At least three fast PCs, loaded with relevant software (multiple GIS packages, a drawing package, and Google Earth being the most important), and a fast, secure (and reliable) Ethernet connection. A dedicated fast color laser printer (for A4 and legal size prints) and a large format plotter are also needed. The plotter would be used for posters, while the smaller color printer would be used to create the mini-atlases and other maps for the response teams. These are the minimum requirements. The LSU team quickly realized that more was needed for an event on the scale of Katrina.

As an example of how this equipment was utilized in the EOC, one PC would be permanently running Google Earth allowing for coordinate relay to response teams, one PC would be sending printjobs to either the printer or plotter, and the third PC would be used to perform GIS operations and create maps. However, if a map was projected on one of the EOC screens, then that PC would be temporarily lost.

During Hurricane Katrina it became immediately obvious that this equipment set-up was painfully inadequate. First, and probably unique to the Louisiana situation, two PC’s dedicated for GIS work, and the plotter, were older and slowed down processing, especially when submitting print jobs. This situation led to various labs volunteering laptops and even a new plotter for our group to use in the EOC. However, even with faster equipment, the LSU team realized that most GIS processing should be farmed back to the computer labs at LSU where multiple machines and plotters were located. The EOC should act primarily as a request collection center, with only extremely time-sensitive GIS operations being performed there. This had the additional benefit of mitigating the high-stress environment for those stationed at the “GIS desk”.

The university setting provides the perfect environment for such remote data processing and product fulfillment. Most major universities contain multiple computer labs, many running GIS, supported by a large university-wide computer support team. The computers and plotters found in these labs are also likely to be faster than most found in a traditional state EOC.

The one caveat in using such a University based support system is that the EOC must have a good Ethernet connection allowing for a reliable and fast two-way flow of EOC requests to the supporting computer labs. The returning product would usually be in the form of a scalable PDF, which could be printed or displayed in one of the three previously described cartographic formats. Alternatively, many poster size maps were printed at the university and delivered by hand to the EOC.

It also quickly became clear that in providing spatial support to a catastrophe of this size, a dedicated server is needed. All products and data collected need to be stored in a central accessible site allowing multiple user access. A system is needed whereby the many labs producing data can upload, through a secure VPN connection, allowing other computer labs to access data and fulfill the cartographic requests. In addition, select non-university groups could also benefit from the data warehouse contained on the server through the same VPN connection. Although in a small disaster this server should be found at the EOC, for a major catastrophe, where multiple computer labs are in operation, a centralized server with adequate storage and maintenance capabilities is needed. Again, a university is well equipped for such a task. Not every university contains a super computer cluster such as LSU, though all have to work with a backbone usually connecting multiple research labs.

Data

A further benefit of involving a university as part of the EOC response team is that systems can be developed with one eye on research opportunities. Obviously, the primary concern in developing a geospatial response support system is making the system efficient and effective for the immediate task of saving lives. However, in developing this support, the LSU team learned that much of the data created during other disasters had been perishable, which in turn severely limited post-event research. Archived data and the resulting research can improve mitigation and future response strategies.

With this thought in mind, the data warehouse implemented for the initial response began to evolve with the goal of preserving all data collected, including an extensive arsenal of aerial and satellite images. New data accessing software was developed with the help of the Intergraph Corporation allowing for users to browse these data sets by geographic area. Data can now be accessed in a spatially registered form irrespective of whether the user is running a GIS or not. This tool was not developed in time to be used for the response itself, but the seeds were sown during this time, and the data being created, the personnel creating it, the location of where these data were created, and the fact that the overseers of the system were academics, all contributed to its creation. It is unlikely whether a purely EOC based response would have resulted in the same outcome.

With a fully operational support-computer lab at the university, the types of requests performed at the EOC itself should be limited to finding coordinates and printing. Although one would think that a GIS should be heavily involved at the EOC, most response requests do not actually need the analysis capabilities of such a system. During the initial response to Hurricane Katrina, search and rescue teams were flown in from every corner of the United States. These drivers had no knowledge of local roads. Although an initial response was to create street files in the GIS, it was soon realized that PDF versions of city maps exist, and these were all that was needed. In fact, many requests can be fulfilled using Internet sites. For example, a typical request during the response was to find coordinates for helicopter rescue teams. By using Google Earth the helicopter pilot could be given the coordinate of a clinic, and at the same time view the high resolution aerial photograph showing potential landing sites. Flood imagery could also be overlaid within Google Earth, allowing for New Orleans city officials to identify if storage facilities containing hazardous chemicals were under water, and again where to set down a helicopter. A graduate student began an on-going dialogue with Google Earth resulting in the manipulation of flood data being translated into overlay files (.kml files that work similar to .shp files) that could be used on any computer running Google Earth. It should be remembered that this GIS to Google Earth link, though common now, was in its infancy during the response. It was an academic mindset and tenacity that led to this implementation during this stressful period. The success of using Google Earth soon spread. The Office of Public Health had its own GIS EOC, which, by the standards of the State EOC, was data poor. Once members of the LSU team had loaded the flood overlay for them in Google Earth, they too had a tool for directing ambulance search and rescues teams. Without university involvement it is unlikely that such a hugely beneficial development would have occurred.

Although the use of Google Earth was a major advancement resulting from the response to Hurricane Katrina, it does not mean to say that it lessens the amount of GIS and Remote Sensing that was needed in order to fully support the EOC, and in order to perform any GIS operation, data are needed. These data needs fall into two major categories; the data you have and the data you don't. Although this may seem somewhat of a glib statement, it is painfully true. There will always be some data sets that are not available and need creation/processing time. A good example is the daily processing of ICONOS and SPOT imagery which were made available immediately following Hurricane Katrina to identify those areas of the city under water. These images had to be processed, either to form a raster coverage or to be turned into a vector layer for overlay on city street maps. Other post-disaster data processing includes address matching, though this proved to be more efficiently farmed out to private vendors who already worked in close contact with university-based projects. In addition to these data sets, unfortunately, other data were not available that should have been permanently housed at the EOC, or at least on the server at the supporting university. Data that should be permanently available on the EOC computers includes standard city infrastructure data (street files, DOQQ, DLG, census data). In addition, pre-geocoded data layers of sensitive buildings, health units, and pre-determined evacuation shelters, should be available. These should also contain all relevant attribute information (how many beds, etc.). It is not enough to know of a dataset's location, such as at www.Census.gov, but rather preprocessed and easily workable layers should be stored on the supporting server. The role of a good EOC support person would be to identify which data sets were important and collect them when not in disaster-response mode. It is likely, however, that oversights will occur (such as the lack of PDF street atlases), due to the fact that it is impossible to predict all data requests in a major catastrophe. In the case of Hurricane Katrina, digital files of levee locations, building footprints, and state owned land (for temporary shelter locations) would also have proved to be extremely useful as immediately accessible files.

The advantage of involving the university in the spatial response is that many of these data layers not available at the EOC are likely to be found in an academic department or a research unit. Failing that, most state agencies have contacts within the university so the right name and telephone number can be quickly found. In addition, it is likely that members of the university team will also have a good idea as to whether the data exists or not. If data is unavailable, the university also contains a large army of skilled workers who can create data layers, for example through digitizing hard-copy maps. It is unlikely whether an EOC based team would be as efficient. As one example of how hard it is to work in isolation, the GIS EOC desk for the Office of Public Health was severely limited to data that already existed on their computers. Their GIS personnel did not have the time to search for other data or process data as they were stretched thin by providing maps and support for their own response teams.

University data sources, such as LSU's Atlas (www.atlas.lsu.edu) can provide much of the basic data, while a system for data sharing among agencies should be in effect for providing more sensitive data.

If we return to the three typical products mentioned at the beginning of this paper—posters, projections and hard copy atlases—all of these require considerable data availability and processing that is unlikely to ever be achieved in the EOC during a catastrophe.

Finally, the size of the university team allows for more interesting data products to be developed. One example during Hurricane Katrina involved the processing of imagery needed to fly an unmanned probe across New Orleans. The comment made by the unit flying the probe was that it was easier to gain appropriate imagery in Iraq than it was for New Orleans. Although the initial contact was made at the EOC spatial support desk, it was a graduate student working by himself who eventually satisfied their request.

Personnel

During the height of the spatial support to the response, the preferred team size working the EOC desk was three, with an occasional overseer watching proceedings. In general one individual would provide coordinate support, one would take requests and one would perform GIS operations and submit print jobs.

During a catastrophe extending over two to three weeks and working on our internally-defined basis that seven hours of highly stressful operation support was the maximum that anyone should work in any 24 hour period (though faculty, staff, and students regularly exceeded this limit in order to fulfill requests), we determined that for our operation to be effective in the EOC we would require at least nine members, plus overseers. Unfortunately, and as discussed previously, this is if a fully functional support operation was backing the EOC desk providing the majority of data development, GIS operations and cartographic design and printing.

Although no exact figures exist, the number of graduate students, research associates, technical support staff and faculty involved at LSU and working with the EOC desk easily exceeded forty. The number of agencies and organizations asking for support, both of in-state and out-of-state origin also exceeded forty.

The university is one of only a few environments where such a large number of skilled people can be mobilized, and as importantly, controlled under an existing administrative system. Even if multiple academic units are working together, these still respect a hierarchy that can, if necessary, be used to mandate operational procedures. The gathering of such a large volunteer force from multiple government

agencies and private companies would likely suffer because of this lack of command as competitors vie for control.

Developing a Management System

During most disasters a small EOC team trained in geospatial technologies will probably suffice. However, as mentioned at the beginning of this paper, a catastrophe will swamp both existing infrastructure and response protocols. University personnel are often flexible in terms of modifying research approaches. This flexibility is partly a result of viewing with a critical eye and seeking to make improvement. It is unlikely that any EOC spatial support approach would be sufficient when dealing with a catastrophe. For example, during the first few days of the disaster all requests at the EOC desk involved a paper filing system. Unfortunately, this system was at best impossible to search for previously developed products, and at worst, was completely ignored. The danger was for duplication to occur. This situation was exacerbated by having no common labeling system and centralized filing location. The team working at 11:00am in a considerably stressful environment would not be aware of the maps produced at 5:00am for daily mission planning. The first step to reducing this inefficiency was to create the data warehouse at LSU that allowed for the products to be stored in a central location with universal access and not solely on a single computer at the EOC. Second, a common filing convention was developed with the input of the LSU map librarian. Third, an electronic tracking system allowed for requests to be taken, sent to the correct individual at the support lab at LSU, reminders generated, and finished products date-stamped. Although any future catastrophe occurring in Louisiana would benefit from this tracking system, as does the current expansive recovery operation, the seeds for its development germinated through university-based brainstorming sessions. It is unlikely a purely EOC based operation would have been as successful.

The X factor

Inside the EOC everything happens quickly, with requests being shouted amidst the general activity of the overall response operation. It has previously been stated that the minimum number of personnel needed for response was nine, plus overseers. It is not enough to simply count any nine skilled GIS workers, however, as it takes a certain temperament to work through the night, to be ordered by high ranking military officials to perform tasks, to be bombarded simultaneously with multiple tasks, to have computers and printers break, and to be exposed to the daily EOC updates telling of the devastation unfolding in your own backyard. In addition, graduate students would occasionally, and by mistake, have members of the public channeled to them as they searched for loved ones. These emotional telephone calls understandably had similarly emotional effects on the graduate students. It is therefore important to have a large enough pool of workers to allow for some fluctuation in personnel as no training can adequately prepare for the stresses of a catastrophe. Again the university environment contains such a size pool.

These stresses also occur from the living environment, including (in the case of Hurricane Katrina), no power in the home resulting in no air-conditioning, bumper-to-bumper traffic dramatically increasing driving time, shortages of essentials in the stores, and having to house displaced friends and relatives. In addition, members of the EOC team may be impaired by having direct contact with the catastrophe-effected region, either losing property or loved ones. During the initial response some members of the LSU team had to work while not hearing from loved ones, while others from New Orleans simply disappeared. The point to be gleaned from this “X” factor is that a large support system is needed to cope with all these staffing uncertainties (Curtis et al 2006; Eichenbaum 2002).

The stress of the EOC also does not provide the ideal situation for effective decision-making, nor for an appreciation of the larger picture. A common finding during Hurricane Katrina was that everyone wanted to help, to “get-their-hands-dirty”, to be saviors. A more distanced objective outlook can provide necessary system adjustments which are lost on those in the EOC. The relative calm of the university allows for such objective decision making behavior. Although no one wanted to upset those who were working at the EOC, it became apparent that some of the decisions made, sometimes by individuals working for stretches of twenty-four hours at a time, were not effective. This experience is likely to be found in other EOCs where traditional staff are overwhelmed with the sheer size of a catastrophe. Although there is always the worry of territoriality, an ideal situation would have an overseer at the EOC reporting back to a decision making team of experienced faculty and staff housed at the University.

The EOC University Partnership

This paper has shown, using Hurricane Katrina as an example, that a state EOC is likely to be unprepared to cope with all geospatial data requests generated during a regional catastrophe. A major university offers the equipment, infrastructure, expertise, and staffing needed to cope with even the largest disaster. It therefore makes sense that these partnerships are solidified before a disaster occurs. Although the LSU "GIS desk" at the EOC was superb, indeed many agencies commented on how it was the best they had ever received during a disaster, the group was still thrust into the situation with little preparation. Many of those involved had never read any disaster related papers or working papers. It would have been useful to know of some of the same issues and solutions faced by those working in the aftermath of September 11th as they are transferable. It is therefore important to involve the university team as part of the EOC response effort, with regular briefings and brainstorming sessions scheduled to keep the larger team as prepared as possible.

In addition, there is discussion at LSU that the university will take a more active role in the running of the spatial support desk at the EOC. If this happens, all students taught in introductory GIS classes will be exposed to the types of tasks performed during an emergency so that a perpetual support group is always in place.

It is, however, more than just the physical size and connectivity of the university environment that makes such a partnership with the EOC so valuable. The university provides a pool of creative minds that in times of trauma can see possibilities and improve any system. Certainly, the university resource cannot be employed effectively and efficiently without pre-existing emergency plans enacted by the institution. For example, as LSU only received minimal damage from Katrina, faculty, staff, and students were able to fully access the resources that supported the EOC operation, such as the CADGIS Research Lab. In addition, Chief Ricky Adams of the LSU police states that, "The university was fortunate to have an established relationship in place prior to Katrina and Rita between academics, students, faculty, staff, and key university emergency operations personnel. This helped the university address the crisis and meet the many needs placed on the university and its resources.”

As a result of Hurricane Katrina the LSU team has created the first Red Cross disaster assessment GIS which can be used to validate existing damage models, and may result in a technological change in the way Red Cross damage assessment data are collected. A data warehouse and tracking system (LSU GIS Clearinghouse Cooperative) is now being discussed by FEMA as the template to be transferred to all other disasters. Data are now being stored to help improve the response to future disasters. All pet-rescue related data collected by Chameleon Beach at animal shelters are now being fed continuously to LSU for research purposes, and the ongoing development of spatial displays in Google Earth (and other newly emerging web-based technologies) will certainly prove to be an invaluable tool in future response efforts. These are only a few of the university led advancements emerging from Hurricane Katrina, all of which directly evolved out of LSU team members working in concert with the EOC.

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