An assessment of geo-information use during the 2005 Kashmir earthquake response and recommendations to improve future use

Wiley C. Thompson

Department of Geography and Environmental Engineering,
United States Military Academy,
745 Brewerton Road West Point, NY 10996, USA
Email: wiley.thompson@usma.edu

Abstract: The destructive effects of disasters on vulnerable populations will continue to increase as global inhabitants grow in numbers and occupy marginal, often hazard-prone areas. Recent experience has shown that there is a gap between available Geographic Information System technologies and geo-information management tools and their employment during disaster response operations. The goal of this paper is to examine and critique the use of geo-information and related technologies in the Kashmir earthquake of October 2005, discuss what researchers have done to address this topic and make recommendations for improving future geo-information accessibility. This paper draws on observations from the 2005 Kashmir earthquake and available literature to examine impediments to operational geo-information management and utilisation during that relief effort. The paper concludes with recommendations on how to increase the accessibility of geo-information to a diverse group of users and better manage geo-information during future disaster response efforts.

Keywords: disaster response; disaster management; hazards; geo-information; GIS; information management.

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Biographical notes: Wiley Thompson is an Associate Professor of Geography and Deputy Head in the Department of Geography and Environmental Engineering at West Point. He led the US military aviation response during the 2005 Kashmir earthquake.

1 Introduction

The Kashmir earthquake of 8 October 2005 killed an estimated 79,000 people, injured twice that number and displaced up to 2.8 million inhabitants. This large earthquake – high death scenario – is likely to repeat along the sub-Himalaya of South Asia in the near future. While the reported numbers of dead, injured and displaced people may vary by source, they still suggest that this was a notable disaster, with the high costs paid in human lives. This work is based on the observations of a relief planner, who was on the

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ground by the morning of 10 October and spent the next 30-plus days planning, coordinating and executing relief support at all levels from Islamabad to the farthest extent of the affected areas. The goals of this paper are to: (a) examine and critique the use of geo-information and related technologies in the Kashmir earthquake of October 2005, (b) discuss what researchers have done to address this topic, and (c) make recommendations for improving future geo-information accessibility. Implementing the recommendations in this paper will enable the humanitarian community to leverage available geo-information and technologies so that responders can conduct future relief efforts in a more efficient, effective manner.

Response in a disaster includes rescue, relief and the initial activities involved in recovery (Thomas et al., 2002; Cutter, 2003). For a variety of reasons provided below, many have criticised domestic and international responses to the Kashmir earthquake. Among the criticisms cited were that relief was slow to get to the mountainous areas (McGirk, 2005), that the initial response from the United Nations "was confused and inadequate" (Kronenenfeld and Margesson, 2006, p.CRS-30) and that a "disaster management plan was lacking" (Sheikh, 2005, p.747). Hicks and Pappas (2006) noted that there was an overall lack of coordination. Sheikh agreed, writing that the "relief efforts were not coordinated" (2005, p.747).

Invoking current philosophy regarding the origin of disasters, one scholar expressed concern that the "Kashmir earthquake was actually a social, not a natural disaster" (Ozerdem, 2006, p.398) which was compounded by pre-existing physical factors and induced by an inept response from a host of actors. Other criticisms include donor fatigue on the heels of the 2004 Indian Ocean tsunami and the xenophobic tendencies of the Government of Pakistan, both of which served as impediments to the relief effort. A collective failure by all actors to fully assess the impact of the earthquake and the widespread devastation that resulted may also have contributed to the slow start. As most of the damage was in Kashmir, an area with a limited, military-controlled communications infrastructure, delayed, sporadic and, at times, inaccurate reporting resulted. Each critique has merit, depending upon the information or framework used to make the assessment. Hicks and Pappas (2006) along with Sheikh (2005) may have come closest to assessing what the planner in this study observed to be the principal impediment to a coordinated response in Kashmir − a multi-level failure to coordinate, track, share and monitor information regarding rescue and relief actions. Failures in coordination during a disaster response result in costs that are paid by those who died from lack of aid or rescue, watched their injuries worsen while waiting for help, or will endure unnecessary hardships long after the relief effort is over.

The United Nations noted that relief efforts require among other things "the development of coordination mechanisms at different levels" (UNS, 2005, p.4). Coordinated efforts disaster response should result in both efficiency and effectiveness of action among contributing actors (Taylor, 1986). Efficiency is "the avoidance of material waste, [and] duplication of effort," all of which should be achieved with minimal application of resources (Taylor, 1986, p.70). Effectiveness implies that aid gets to those "of greatest need" (Taylor, 1986, p.70), that the aid matches the need and that there is an impartial and complete coverage of aid distribution. In Pakistan, disaster responders failed to employ geo-information and available technologies effectively to coordinate humanitarian action. This resulted in ineffective, inefficient relief and delayed universal coverage of relief aid.

In order to improve the effectiveness and efficiency of future relief efforts, researchers must examine the problem of how disaster responders can share information in a manner that allows tracking and total visibility of all relief actions in a proven system. The action of a relief actor has consequences. Relief actions have first- as well as second- and third-order effects on disaster victims and other actors. If actors are not aware of the actions of others, their activities may result in duplication of effort, omission of effort and even unintended negative consequences. The disaster area places limits on an actor's ability to see or know what is occurring within the 'disaster space'. Mountains or forests can limit an actor's visual sense and immediate geographic understanding. If an actor is not aware of the actions of other actors in the vicinity, it can become very difficult to plan future disaster response activities.

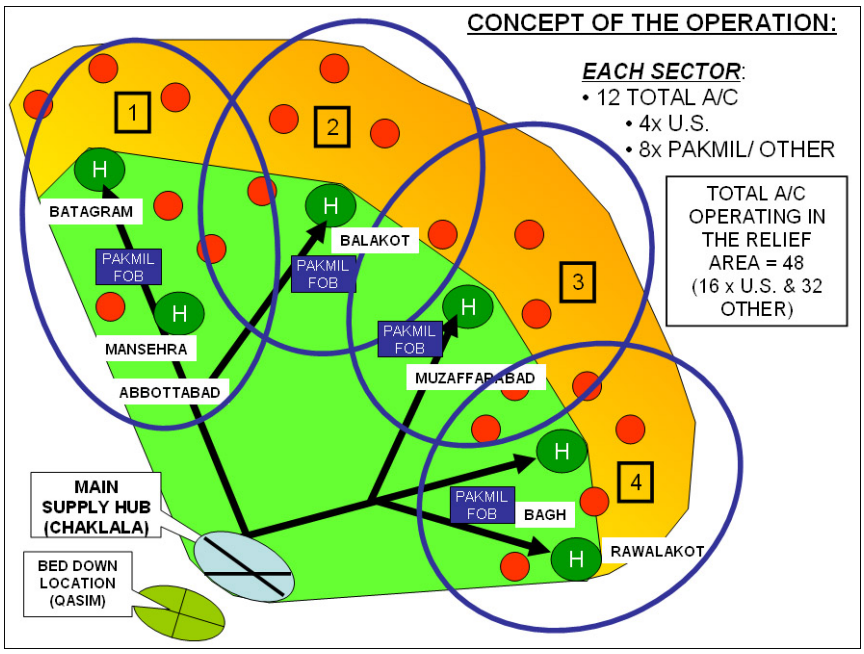
To coordinate the activities of so many participants in a large operation, such as the relief effort in Kashmir, one must use a map. In fact, maps are so important to disaster response that the National Research Council (NRC, 2007) published a recent report *Successful response starts with a map*. Fortunately, a map, or better yet a Geographic Information System (GIS), allows people to see beyond the limits of their physical senses and immediate geographic understanding. Similar to descriptions by Friedman (2007) of a 'flat world', a GIS can 'flatten' the disaster space, eliminating the curvature of the geo-information horizon beyond which people can sense. Distributive technology, such as the internet, enhances flattening. Once the disaster area is flattened, response planners and decision-makers can portray the actions of others by depicting what has happened and where it has occurred. Armed with a more holistic understanding of the problem at hand, planners and decision-makers can see opportunities where effort is lacking and can avoid locations where action would duplicate the previous effort of others.

Collaborative mapping activities in a disaster space are an essential step in coordinating the activities of disaster responders. While responding to a disaster, actors may find themselves differing greatly from others in their perceptions of "space and place" (Alexander, 2004, p.150). Differing perceptions of activities and space can create a fusillade of conflicting or duplicate management decisions (Goodchild et al., 2007). Maps and the geographic information (hereafter referred to as geo-information) they display are essential to coordinating large or complex operations. Geo-information unites "location in space-time" with a "set of properties" (Goodchild et al., 2007, p.251). Geo-information tells a user what it is, where it is and when it happened. Geo-information and the technologies used analyse, manipulate and share these types of data, and can reduce conflict and prove to be "critical inputs to incident management and tactical decision making" (NRC, 2007, p.53). Using a GIS to display and analyse geo-information is especially useful as a decision-support tool during all phases of a disaster (Cova, 1999; Thomas et al., 2002); however, planners will find this capability most useful during the early stages of a relief effort. Early access to such information assists planners as they analyse and assess past actions, predict future movements, increase the efficiency of relief operations and ensure universal coverage of aid.

The ability to access geo-information during a crisis is empowering. In a distributive and collaborative environment, small actors can 'see' what large actors 'see'. Equal access to geo-information also allows each actor to visualise what others are doing and provides each participant with a common sense of the disaster space. Aside from the expected problems associated with a large-scale relief effort start-up, it is likely that one of the greatest factors impeding the initial push in the Kashmir earthquake relief effort was that organisations participating in the effort could not coordinate their actions with

those of others because they did not have a 'common operational picture' (Figure 1). Military doctrine describes the phrase, common operational picture, as "a single identical display of relevant information shared by more than one command" which "facilitates collaborative planning and assists all echelons to achieve situational awareness" (Joint Publication 3-0, GL-11, U.S. Department of Defense, 2006). In order to build a common operational picture one must have geo-information and the tools to collect, process, display, distribute and archive data.

Figure 1 A concept map developed by a US aviation planner (S. Halter) in Pakistan. Even without terrain data or high-resolution imagery, maps that depict the actions of others provide users with a basis for a common concept of space in a large operation, give relational attributes to mapped data, and eliminate conflicts of space and activities resulting in safer, more efficient operations. Such products are often the basis on which a common operational picture is further developed for a complex operation (A/C stands for aircraft) (see online version for colours)



2 The role of geo-information in disasters

Geo-information scientists have written a great deal on the subjects of GIS in disasters and emergencies (Alexander, 1995; Coppock, 1995; Cutter, 2003; Greene, 2002; Laefer et al., 2006; NRC, 2007; Thomas et al., 2002; Waugh, 1995; Wood, 2000) and spatial decision support systems (Cooke, 1992; Herold et al., 2005). They have contributed to the very technical subjects of interoperability, accessibility, ontology of geo-information and information sharing (Abdalla et al., 2007; Bakillah et al., 2007; Mansourian et al., 2005; Xu and Zlatanova, 2007), as well as the challenges of using GIS for disaster response (Zerger and Smith 2003; Abdalla et al., 2007). Even newer subjects such as the

employment of open-source, grassroots or alternative solutions to disaster management (Singel 2005; Cai et al., 2006; Careem et al., 2006; Chang and Li, 2007; Goodchild et al., 2007; Palen et al., 2007; Pezanowski et al., 2007) are well documented. Geoscientists have and continue to make meaningful contributions to the application of GIScience in emergency and disaster management. The humanitarian community must now take available technology and create an internet-based GIS, which provides one-source, all-hazard, continuous, global disaster coverage. If done, this will enable greater coordination in future humanitarian efforts.

Information that captures the space, time, and attribute data of a disaster is most useful when it is shared among a large field of users while simultaneously retaining the ability to collect more information. The internet is a sharing tool. The internet provides the ability to collect, publish and make available geo-information to a broad array of users by means of an online GIS, which is especially useful during a crisis (Mansourian et al., 2005; Boulos and Honda, 2006).

The first step to making geo-information available to those responding to a disaster is to collect, consolidate and organise geographic data in a data clearinghouse (Mills et al., 2008). Following Hurricanes Katrina and Rita, a group from Louisiana State University (LSU) cooperated with the Federal Emergency Management Agency to do just that. They developed the LSU GIS Clearinghouse Cooperative (LGCC). This cooperative effort created a data clearinghouse, which provided a repository of geospatial data immediately following the hurricanes. This database is still available today as an archive of data from the two disasters. Models such as the LGCC are a valuable source of data and a key component of the proposal in this paper.

An example of a web-based initiative that facilitates geographic and non-geographic information exchange is Sahana (http://www.sahana.lk/). Sahana provides registries and management tools to assist both victims and disaster relief planners. However, this application would be much more useful if it included an online GIS and allowed relief planners to retrieve or submit spatial data collectively. GeoWorlds (Neches et al., 2002) was an initiative that sought to integrate GIS capabilities, spatial and document libraries, and three-dimensional visualisation in an internet-based application framework. While GeoWorlds did not address a broad-spectrum of user needs, nor examine implementation at a global scale, it did validate the viability of online GIS, which allows broad-spectrum users to access geo-information in as many formats as possible and has greater diversity of functionality. Herold et al. (2005) proposed a system that integrated GIS and spatial databases in an internet-based environment. Their self-described internet GIS incorporates Open Geospatial Consortium interface specifications and allows for user input in the form of the creation of points, lines and polygons on a map. Calling for standardised interfaces and data formats is critical to successful implementation of a large-scale GIS. Furthermore, allowing users to contribute data is valuable because it addresses the needs of users without robust GIS capabilities but who have a need for more than static maps.

Relief planners have employed GIS and leveraged geo-information in previous large-scale relief efforts. GIS played a central role in the response to the New York City World Trade Center destruction in 2001 (Galloway, 2003). During the 2004 Indian Ocean tsunami relief effort, shared geo-information made for a more efficient and effective effort (Boulos and Honda, 2006). Global Connection Project (GCP, 2008) was a key player in the drive to make high-resolution imagery available during Hurricane Katrina in 2005 and the 2006 Bantul Indonesian earthquake. In each crisis, geo-information

provided valuable data to relief planners and decision-makers. However, while of great value for each particular crisis, the initiatives were event-specific and did not provide the variety of geo-information products and functionality that would accommodate a diverse set of user needs.

Although some may not see Digital Earth applications as a true GIS, it would be an oversight to write about geo-information in disasters and not address them. A commonly known Digital Earth application is Google Earth. Some (mainly GIS and Society scholars) will argue very strongly that Google Earth and other Digital Earth applications are not GIS. While Digital Earth applications do not possess the powerful analytical capability of a true GIS, they require less funding to purchase software and minimal operator training, making them an attractive tool for disaster management. As suggested by some, Digital Earth applications such as Google Earth or GIS/2 applications like Google Maps are viable, alternative disaster relief and crisis management tools (Miller, 2006; Pezanowski et al., 2007). Other non-GIS-specific alternatives for collecting and making available geo-information reside in the public participation wiki realm. A wiki allows individuals to contribute to collaborative projects such as online encyclopaedias, dictionaries and maps. Public participation wiki projects during Hurricane Katrina (Singel 2005; Palen et al., 2007), the 2007 California wildfires and even an Avian Flu forum (Palen et al., 2007) have demonstrated the ability to collect and share a wealth of information from a very diverse group of participants by using the internet.

3 Geo-information in Pakistan

As noted by an NGO staff member during the 2005 Kashmir earthquake relief effort, "If we had good maps, we would be on top of things" (Currion, 2005, p.17). This correlates with observations made during the research for this study. The staff member's remark suggests a lack of situational awareness and a failure to develop a disaster-wide common operational picture. However, the statement also indicates that there was awareness among those conducting relief operations that the ability to display time–space–attribute information in some format, either hardcopy or digital, would have been of great value, if not a necessity.

Kashmir earthquake responders employed geo-information and associated technologies to a limited extent in that relief effort. The United Nations' Humanitarian Information Centre made their *Who is doing what where?* maps and other products available via ReliefWeb (www.reliefweb.org). MapAction (www.mapaction.org) deployed to Pakistan in support of the United Nations Disaster Assistance Centre. They produced numerous map products during the initial earthquake relief effort. Global Connection Project (GCP, 2008) worked with Google Earth to make 1 m resolution IKONOS imagery of the earthquake area available in the Muzaffarabad, Mansehra and Abbottabad districts (Nourbakhsh et al., 2006). Developers also deployed Sahana to Pakistan to support the relief effort and continue product testing. Maps and products available to planners following the Kashmir earthquake were useful at a very coarse scale, but lacked the fine granularity required to be most beneficial to disaster response planners and decision-makers on the ground. Additionally, the inability to input response actions from actors, the lack of interactivity and limited functionality of these products further handicapped their utility to relief planners. Information available on each of these products would

have been much more useful if planners and decision-makers had combined it with geo-information detailing relief actions of each organisation as well as existing aid requirements.

The US Army's 12th Aviation Brigade (Task Force Griffin) was the largest operational foreign military aviation contributor during the relief effort (Thompson and Halter, 2006). The 12th Brigade had the responsibility to provide rotary airlift capability to the Government of Pakistan, other humanitarian actors, and advise the US Joint Task Force Headquarters on the matter of aviation capabilities and utilisation. Although not ordered to do so in writing, the 12th Brigade also took on the responsibility for receiving and integrating foreign military aviation units as they arrived in Islamabad.

The Pakistani Army General Headquarters (GHQ) was the mission approval authority for aviation resources during the relief mission in Kashmir. Representatives from the GHQ coordinated all activities at the disaster relief-loading zone on Chaklala Airbase in Islamabad. GHQ planners collected relief requirements and then sought to source them with rotary wing assets if appropriate. Appropriateness meant that there was either an immediacy of need which a slower method of delivery could not satisfy or that ground assets could not reach the affected area. Many civilian relief agencies and all of the foreign military aviation units participating in the relief effort operated primarily out of Chaklala. Two key actors, which did not appear to take aviation support requests from or coordinate directly with the GHQ at Chaklala Airbase, were the United Nations Helicopter Air Service and the International Committee of the Red Cross (ICRC). However, the author notes that the ICRC did initially attend the GHQ nightly aviation coordination meetings.

Although one author levelled criticisms at the US aviation relief effort (Ozerdem, 2006), rotary wing resources were the key to the success of the initial rush to provide relief (Thompson and Halter, 2006). In fact, civilian and military aviation operations were a major component of the overall earthquake response in Pakistan. Aviation asset employment during the earthquake response reflected the failure to use geo-information to plan and coordinate affected relief activities. Helicopters are a terrain-independent mode of transportation, and as such, aircrews were the first formal response components to reach some affected areas. Aircrews were able to cover more ground and observe more damage each day than ground-based relief actors. The question must be asked now (and should have been asked back then) why weren't geo-information and technologies used to plan the helicopter utilisation? As aircraft and aircrews are low-density, high-payoff resources, planners must use them in the most efficient manner possible. Efficient use includes going after hard to reach targets and minimising ground time in order to achieve maximum work per blade hour. Beginning on 10 October, US military aircrews flew in excess of 1500 hours in their first 30 days in country (Thompson and Halter, 2006). Despite this high tally of blade hours, US military aviation planners and aircrews maintained a concern that planners and decision-makers were not employing aviation assets in the most efficient manner.

Inefficient use of helicopters occurred often. An example of this type of ill-coordinated use occurred when two large aircraft, capable of carrying many tons of aid and evacuating upwards of 40 casualties each, arrived at a destination only to find an aircraft with the capacity to evacuate only four injured people shut down on the landing zone. The two large helicopters would then have to remain in a holding pattern for upwards of 30 minutes. This was a waste of time and fuel, but more importantly, it decreased the probability that the large helicopters could make an additional sortie to the

relief area at the end of the day. If relief planners had used geo-information to build a common operational picture, they could have been able de-conflict destinations by time and space. Doing so would have avoided the inefficient use of limited aviation resources.

Aircrews also used valuable flight hours on missions to deliver aid to destinations that were either already well stocked with the same aid that was onboard the helicopters (Figure 2) or were in need of different items. There were also occasions, within the first week of the relief effort, in which aircrews sat idle because relief planners did not have the situational awareness to assign aircrews a load or a destination. Worse yet, however, is the thought that as pilots sat idle waiting to be assigned a destination, there were villages, as long as a week after the earthquake, that had not received any aid or medical evacuation.

Figure 2 A picture taken by a US Army helicopter pilot to prove to relief planners that Balakot had sufficient tentage on hand. After viewing this image, aviation planners wasted no additional sorties by sending tentage to Balakot (see online version for colours)

Source: Author

While aware of the benefits of capturing and sharing geo-information, military leadership and planners did not force the establishment of a collaborative geo-information collection system. In hindsight, they should have. Military pilots brought back important data such as road closures, damage reports, reports of aid requirements and assessments of aid saturation. Aviation liaisons captured the details of each mission flown by military aircrews and posted the information on a map in the aviation operations centred on Chaklala. This map was available for any interested party. However, the map contained observations from only one organisation and was not accessible to all relief planners. Therefore, it was limited in its utility. If relief coordinators had had a system that allowed them to share information, observations and relief actions in a collaborative, internet-based geo-information structure, all actors would have had a common operational picture. This would have allowed each organisation to achieve greater efficiencies and effectiveness in targeting aid from the first day.

4 Recommendations

Recommendations for improving situational awareness and coordination during disaster relief should focus on areas of geo-information collection, sharing and product development. Successful efforts in these areas must be both bottom driven and top supported. This means a single coordinating organisation must take responsibility for implementing such an initiative, but the success of the project and usefulness of the products depends on data contributions by each actor. Those conducting relief activities must capture and input data into a collaborative system. Input format and the means to do so should be the same from disaster to disaster. In this manner, the data collection requirements and formats will not change with each humanitarian effort. Additionally, the system must be web-based, as this would enable simultaneous input by actors with internet connectivity from virtually any location.

Figure 3 Author's proposed geo-information structure. This system will provide near real-time, one-source, all-hazard, all-access, global-coverage of ongoing humanitarian response efforts and crises. Maintenance outside of affected areas and support by an in-country staff will ensure reliability and better collection and distribution of data, information and products. The multi-level functionality and complexity will support a more diverse community of geo-information user requirements (see online version for colours)

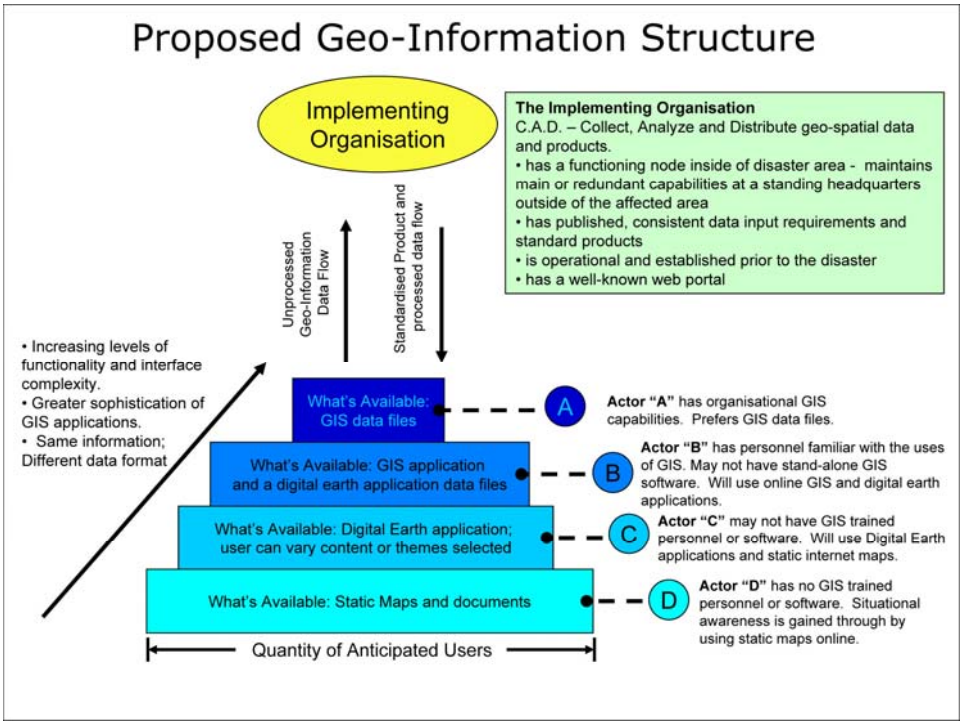


Figure 3 shows a proposed geo-information structure for disaster relief and other humanitarian operations. The pyramid in the centre of the figure represents a series of differing levels of functionality of web-based geo-information. At the top level (top of

the pyramid), users can access GIS data files, allowing their internal, GIS-trained staff to incorporate those data into their organisational planning requirements. The lowest level (bottom of the pyramid) represents an environment where static, digital maps and documents are available. In between these two levels are environments where an online GIS is available and Digital Earth applications such as Google Earth are available. Each level will give the user similar information, and thus a common operational picture. The only variation is the product format and method of interactivity offered.

The width of each level represents anticipated user traffic. While not completed as a component of this research, the suggestion here is that more organisations would be likely to download pre-made maps to satisfy their information requirements and that fewer organisations would require GIS data files for use by their own GIS-capable staffs. One must consider that copyrighted GIS software is expensive to purchase and requires trained operators; each contributes to the cost of maintaining a GIS capability. If GIS use were episodic, many organisations would have difficulty justifying, let alone funding, such a high cost-to-use ratio. The assumptions made here are that more organisations would be likely to require that static maps be available on the internet to satisfy their information requirements and that fewer organisations would require GIS data files for use by their own internal GIS-trained operators. The needs and capabilities of other organisations would likely fall somewhere in between.

In order to ensure the success of the proposal in this paper, a single lead organisation must take ownership for these responsibilities of implementing and maintaining the geo-information structure. The implementing organisation for this project must provide the same level of commitment that the United Nations provide for ReliefWeb. Only in this manner can the humanitarian community ensure continuous, global, disaster coverage. The implementing organisation would collect, analyse and distribute geo-information. They would be the 'map steward'. To coordinate the collection of geo-information, the implementing organisation must have a staff both outside of and inside the disaster area. The staff outside the disaster area would maintain the server on which the system resides, while the in-country staff would collect and forward data from walk-in sources, disseminate products and respond to requests for information. Contributing governments and the humanitarian community must appropriately fund the implementing entity so that the costs associated with staff, training, technology and software do not drive the level of functionality or reliability of service. Likewise, the implementing entity should be a stakeholder in the success of humanitarian efforts. In this manner, as disaster requirements ebb and flow, the organisation will not 'follow the money' to satisfy profit-focused investors.

Individuals and organisations should not have to ask who is going to provide geo-information support each time they deploy on a new humanitarian mission. The intent for the geo-information structure proposed in this paper is for long-standing use, not a transitory, per-disaster effort. In order to ensure continuous global disaster coverage, the portal from which actors access geo-information must be in place prior to the declaration of a disaster. Waugh (1995) noted that experience during Hurricane Andrew demonstrated that GIS deployment "could have made the response more effective and speeded the recovery", but that GIS "databases need to be created beforehand, rather than pieced together in the chaos of a disaster operation" (p.429). It is difficult to advertise the existence of the geo-information website after relief organisations and workers have

already deployed to a disaster-stricken area. The humanitarian community should be as familiar with the website for the proposed system as internet users are with websites like YouTube.com, Yahoo.com, Google.com or Amazon.com. Whether a relief worker is a seasoned veteran or a relative newcomer, he or she should know where to go to get data or contribute geo-information of their own. As previously noted by Mills et al. (2008), a pre-existing website would allow users to get an historical download of response activity prior to their deployment or commitment of resources.

Just as the system proposed in this paper offers a diversity of products, there should be multiple methods with which to search for information about an on-going disaster. Users must be able to go to the web portal and access information on an in-progress disaster or crisis by entering a GLobal unique disaster IDEntifier, by selecting from a country or hazard list, or by locating the disaster geographically on a clickable map. Actors will soon gain familiarity with the formats, methods and functionality of the geo-information website. The ensured 'sameness' in future events will provide continuity while reducing initial pre-deployment information collecting difficulties. Finally, the website must have data available in multiple formats and methods of access including downloadable shapefiles, keyhole markup language (KML or KMZ) files for easy opening in Google Earth, an online, collaborative GIS, and static digital maps and documents. In this manner, every organisation, regardless of geo-information processing capability, will have the same common operational picture and a greatly enhanced state of situational awareness.

Disaster responders are more likely to use a familiar application or website that provides greater functionality, utility and diversity of coverage. As such, one final recommendation is that this initiative serves the humanitarian community at large. Hazard events are transitory, so to avoid designing an application for the 'disaster *de jour*', application developers must account for a wide range of potential contingencies. The proposed website should cover a variety of threats to humanity, such as droughts, land mines, reproductive rights, food security as well as earthquakes. A system that services a greater diversity of needs will continue to be used, improved and, most importantly, funded. Lastly, as a collateral benefit, this proposed geo-information structure would also function as a data repository for each disaster or crisis (Mills et al., 2008). Disaster researchers would find great value in such a collection of data as it would enhance their ability to study past disasters and improve future relief efforts.

As mentioned previously, the geo-information structure proposed in this paper contains similar features found in other proposed designs (Table 1). As such, this proposal is not a new idea, but instead a more complete approach to facilitate the collection and sharing of geo-information. In terms of user interface, what really distinguishes the geo-information structure in this proposal from others is the greater diversity of functionality and the broad spectrum of geo-information available. Both of these features are necessary to address a wide array of user needs and levels of GIS sophistication. Additionally, unlike other proposals, the requirements for full-time implementation, global coverage and ownership by a humanitarian-focused organisation will ensure long-term utilisation. Providing global coverage is also important because hazards do not adhere to political boundaries, so neither should the systems that people use to respond to disasters.

Table 1 Comparison of proposed and existing system specifications/capabilities

	Proposed	Herold et al. 2005	Sahana	Neches et al. 2002 (GeoWorlds)	ReliefWeb	LGCC
Internet-based	X	X	X	X	X	X
Global Coverage	X	X	X	X	X	
All Hazard	X	X	X	X	X	
Static Map Availability	X	X	X	X	X	X
Online GIS	X	X		X		
User Activity Input	X	X	X			
Document Repository	X		X	X	X	X
Humanitarian Ownership	X				X	
Creation of Attribute Data		X	X			
GIS Data Files Available	X		X			X
Digital Earth Application	X					

5 Considerations regarding implementation

Researchers have addressed many considerations regarding the implementation of web-based systems at length in the literature; however, it is necessary to highlight a few considerations that are most applicable to this specific proposal. Data from the field are vital to the success of the system proposed in this paper. Without geo-information, mapping products are meaningless and lack the appropriate context in which decision-makers can view their proposed actions. Actors must record their actions and observations and put these data back into the system. They must ensure their data are "comprehensive, accurate, timely and accessible" (Laefer et al., 2006, p.115).

A potential drawback of a web-based system is that in some locations, relief workers may find it difficult, if not impossible, to access the internet for a given period. This is where the in-country staff could facilitate data collection by gathering information for later input. In other areas, organisations can collect and record data on paper or in digital format and deliver the data to a location with web connectivity for delayed input. Acknowledging that this type of approach does not lend itself to real-time reporting, the fact is that even older data, once entered into a collaborative geo-information environment, allow planners to create a more complete picture of past actions and future relief requirements. Whether relief field workers handwrite geo-information on paper for later input or capture it in real-time on a GPS-enabled personal digital assistant, each bit of data is a valuable piece of a bigger picture.

Those contemplating the viability of the system proposed in this paper may be concerned about existing spatial data availability. In Kashmir, Pakistani Government concern regarding national security resulted in an initial lack of publicly available maps, high-resolution imagery and digital geographic datasets. Future disaster-stricken regions may lack geographic data as costs of acquisition, levels of technological development or competing demands have prevented the collection and creation of datasets or at least relegated these activities to a lower level of government priority. Spatial data availability should not be viewed as a barrier to developing products which will assist in coordinating

efforts and creating greater situational awareness through mapping. Peduzzi et al. (2005) demonstrated that global datasets available during their research allowed them to map 82% of hazard events and 88% of disaster victims.

While it would be ideal to have 1 m coloured, geo-referenced imagery of every disaster area and a geodatabase containing complete population, infrastructure and terrain data, the fact remains that this is not a realistic expectation yet. However, what is reality is that as humanitarian organisations begin to input their observations and activities into the proposed geo-information structure, a blank map will quickly become a useful tool as information begins to paint the common operational picture. Filling in the map 'flattens' the disaster space beyond which relief workers can 'see'. It allows them to visualise the entire disaster area from anywhere. Organisations can then begin to picture their operations within the context of the locations and actions of others, allowing them to plan and coordinate what their next action must be.

GIS designers are very concerned with data format and software compatibility. Initiatives to create a spatial data standard already exist. Hard work by GIScientists has had varying levels of success. Gaining consensus, implementation and compliance in the area of a single data standard is a difficult task. In the context of the proposal in this paper, the implementing agency can eliminate data compatibility issues by adopting a standard − whatever it may be − and adhering to it. Once they adopt a data standard, those wishing to make the most of their efforts in a humanitarian crisis will comply. Finally, because the proposed system is web-based, the issue of software compatibility largely becomes a moot point for the lower three levels of the geo-information structure. As long as users have a compatible web browser, they should be able to access applications and data on the website.

Outside of accessibility during the degraded information technology environment of a disaster, another concern for any web-based initiative is how it will be resourced and maintained. As donor fatigue sets in or other events become more newsworthy, resources which maintain websites may be directed to other initiatives. This was very evident during the 2010 Haitian earthquake. Within two to three months, websites and data portals which were key sources of information during the early days of the response in Haiti were no longer updated. Now as cholera epidemics and displaced persons crises threaten to be the next, but silent disasters, those responding will have to re-energise old sites or create yet another portal to facilitate geo-information sharing.

6 Conclusion

Humanitarian organisations, scientists and researchers have developed web-based disaster information support systems and initiatives in the past and continue to deploy new applications. Still there has yet to be a one-source, all-hazard initiative that supports the diverse, global geo-information needs of the humanitarian and disaster communities. Rapid advances in technology and scientific gains in geo-information science make the rationale behind the lack of a geo-information structure unacceptable. Until the humanitarian community employs a system that provides a common operational picture for all disaster responders, it will continue to fail at attempts to fully coordinate large-scale relief efforts and achieve maximum efficiency and effectiveness. Unfortunately, the

victims of disasters will increasingly continue to pay the costs associated with these failures. Therefore, it is time that leaders in the humanitarian realm take the initiative and flatten the disaster space.

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