COMMUNITY-BASED DISASTER RESPONSE DESIGN USING AN OPEN SOURCE GIS

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ABSTRACT

As global warming contributes to the increased occurrence of natural disasters, the necessity of superior geospatial systems in response management is underscored (Peduzzi et al., 2005). Urban areas receive the bulk of response efforts, however, leaving rural locales at higher risk of isolation after such disasters (Morrow, 1999). In addition, limited funding for disaster preparedness leaves many areas with little or no response framework in place beyond ordinary 'emergencies' such as power outages. Some communities are therefore taking matters into their own hands. Residents of the rural area of Freshwater in Humboldt County, California, a highly active seismic region, are developing a community-based disaster response plan for managing relief efforts until official assistance arrives. We designed an open source, interactive geographic information system (GIS) which allows residents to enter and update disaster relevant skills, resources, and needs into a password-protected PostgreSQL database. Maps and rosters of the information organized by GIS defined neighborhoods are viewable, printable, and updatable by neighborhood 'captains'; resident access is limited to personal data updates and community-level maps. By incorporating rated hazard zone maps for each community, detailed action plans by neighborhood, and other features from programs discussed in this paper (Wei, 2001, Gunes et al., 2000), our system could become a cost-effective, easily transferable community-based disaster management model, filling the response gap in rural areas.

INTRODUCTION

After the catastrophic Hurricane Katrina American citizens were informed that in most disaster situations there would be a gap of up to several critical days before state and federal assistance would arrive due to the logistics of large-scale relief efforts. While counties have generally been thought of as primary first responders, small rural areas are still at high risk of neglect. One such place is the community of Freshwater in Humboldt County, California, whose residents are creating their own disaster response network. They requested a user-friendly spatial database system that will allow them to cross-reference emergency needs and resources; examples include finding the nearest caregiver to a person with medical needs, or the closest chainsaw owner to a road blocked by a fallen tree.

Examples of such community-level organization vary in their levels of complexity. Taiwan is currently at the forefront of community disaster planning as its unique geology and location make mudslides, floods, and earthquakes inevitable. Unorganized disaster response has been present at the neighborhood level for decades already, but the government is now actively promoting their Integrated Community-Based Disaster Management program (ICBDM), which has already been credited with saving lives and reducing response time after disasters. Neighborhood Rescue Team (NRT) development, included in this program, is encouraged "to prepare communities to take care of themselves in the aftermath of a major disaster when first responders who provide emergency services are not able to provide immediate assistance" (Wei, 2001).

Another promising model is from the Douglas County Emergency Management Agency (DCEMA), which worked with the University of Kansas to create a method for flood impact assessment using damage functions in a GIS in order to better determine flooded areas. Three databases were initially envisioned: a disaster/emergency database that allowed different damage extent queries; a facilities database showing locations of important and/or 'at-risk' buildings; and a resources database (ultimately rejected as unfeasible due to cost) that would in theory display all locations of useful disaster response items or personnel (Gunes et al., 2000). These were then overlaid to determine areas of greatest concern. By utilizing separate databases, it was possible to independently adjust the hazard database for use in different disasters and assemble specific response plans according to type of risk.

The community of Freshwater in Humboldt County, California has plenty of reasons to be concerned about natural disasters as the Cascadia subduction zone, the Gorda plate and the North American plate all interact in the Northern California coastal region (Dengler, 1997). On December 26, 1994, for instance, a State of Emergency was declared by the California Governor after an earthquake with a seemingly low magnitude of 5.4 happened only 12 miles from the county seat of Eureka, causing over 5 million dollars in damage (Dengler, 1997). April 25, 1992 marked the Petrolia or Cape Mendocino Earthquake (7.1 magnitude), which resulted in the declaration of a federal disaster with $60 million in damages. In 1980, a 7.1 magnitude offshore earthquake nearly fifty miles northwest of Freshwater even caused the collapse of a freeway overpass. In other words, it's only a matter of time before the "big one" hits, and Freshwater would be very isolated from the state and federal assistance that would appear in the region's more heavily populated areas. Concerned Freshwater, California residents came to the conclusion that they needed a community-level disaster response plan to 'tide them over' in such a situation until official help did arrive.

MATERIALS AND METHODS

Freshwater community members started by delineating 'neighborhood' units (groupings of land parcels common to a road or area that most residents would consider intuitive) by overlaying transparency paper on a large aerial map showing parcels. Neighborhood 'captains' were then designated as focalizers, using disaster preparedness hardcopy forms to collect detailed household data door-to-door in the three broad categories of skills, special needs, and equipment. This information was then transferred to the open-source software for manipulation.

Most GIS emergency work is based on commercial software platforms such as Intergraph and ArcView (Gunes, et al.; Gauthier, 2004). However, due to the high recurring costs and steep learning curves of such systems to community users, we chose to build our system on a locally designed open-source spatial database platform called HostGIS, which utilizes PostgreSQL, "the world's most advanced open source database" (www.postgresql.org), and PostGIS, its spatial extension. The ESRI shapefiles for roads, parcels, and neighborhood zones were uploaded into the HostGIS system and placed into a preliminary web template using the PostGIS file that was automatically created from the imported ESRI shapefile. We then adjusted the source code to customize an interface template with the stated design goals of simplicity and ease of navigation.

The online entry form was designed based on the hardcopy form in an effort to ensure data integrity. (Note that the database functionality is handled using PHP commands, while the objects within the map are contained from within JavaScript). Entries made to the form are thus carried by the PHP file into the database. Each question updates the associated field in the appropriate database table. In addition, integrity constraints were added through the use of primary and foreign keys. All of the tables were arranged in Third Normal Form (3NF) in an effort to reduce the number of tables created in the database and avoid data redundancy. For example, the parcel's table primary key (GID) was used to identify and relate each person to the appropriate neighborhood and household.

Authentication was handled through structured query language, or SQL. SQL statements are executed from within the PHP code to handle data manipulation such as *SELECT, INSERT, UPDATE* statements to the database. Users attempting to use the system without an existing, valid address are unable to enter data. These "*unidentified households*" receive an error message instructing them to contact their captains for further instruction. In contrast, valid existing users are authenticated by their address. Once in the system, authenticated users are able to update the appropriate data without having to re-enter all of the previously stored data. The following Entity Relationship diagram (figure 1, page 3) depicts the relationship among the tables created in the system.

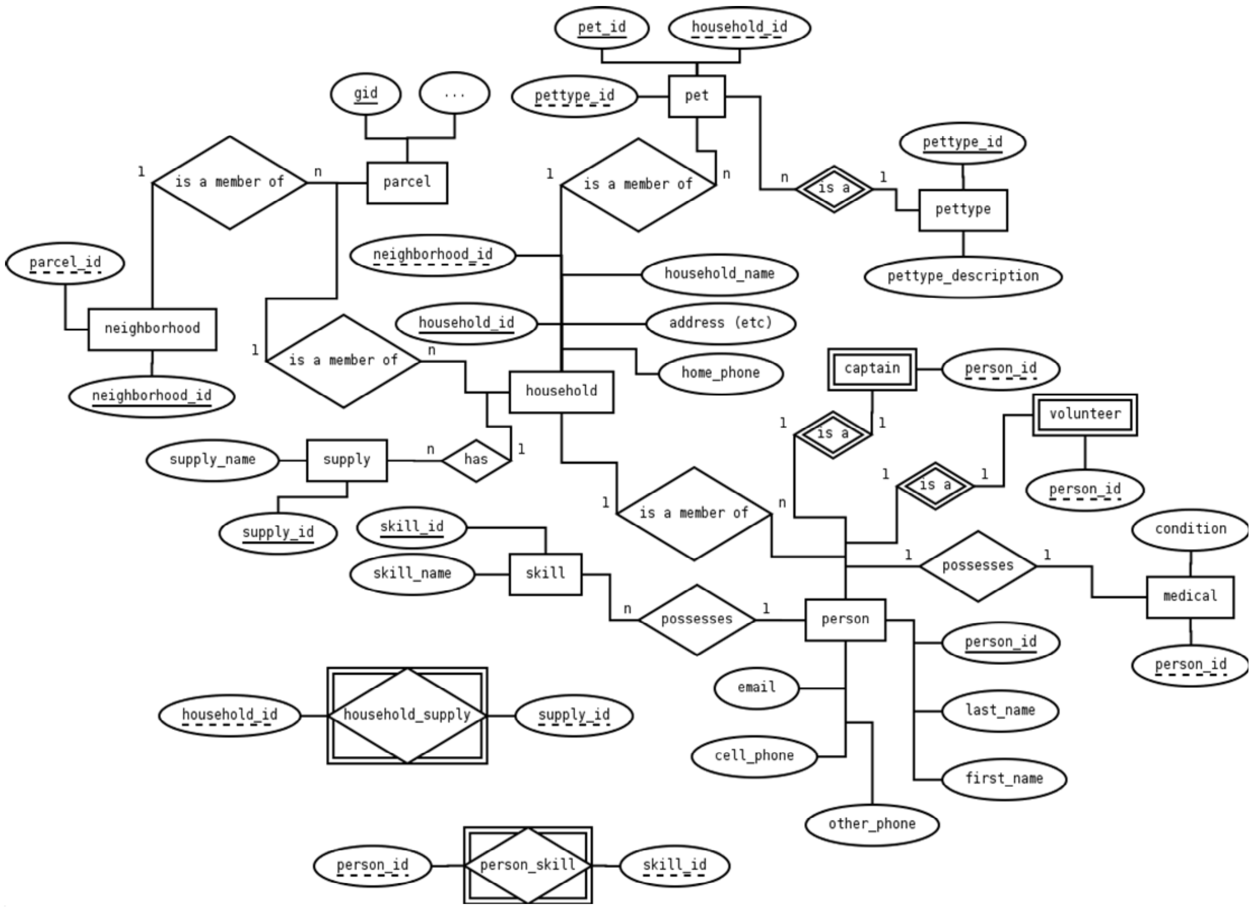

Figure 1. Entity relationship diagram showing the many-to-one relationships between tables in the database. Database entities are represented within a square, while relationships between two entities are linked and represented within diamonds. Entity cardinality is depicted as one-to-one (1:1), one-to-many (1:N), and many-to-many (M:N). For example, a supply has at least one household, while a household can have many supplies.

Our Graphical User Interface (GUI) was designed using some of the basic principles of Human-Computer Interface design including intuitive layouts, ease of use, standardized buttons, and concise questions. An overview of this GUI is found in Figure 2, below.

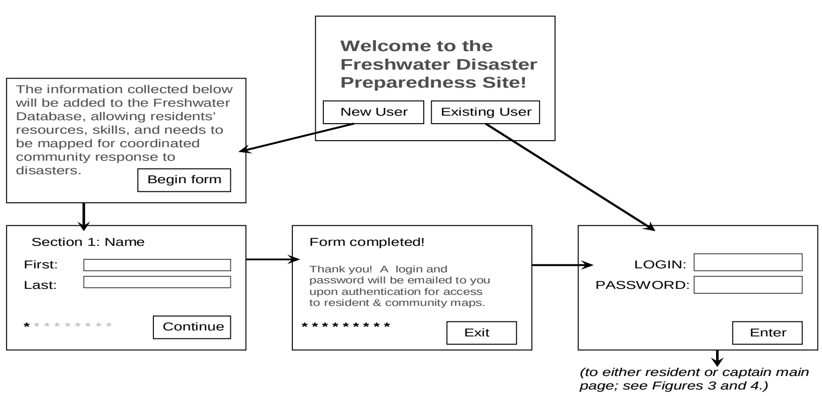

Figure 2. Design schematic of the Freshwater Disaster Management Plan data entry interface.

An existing user will go to the login page, whereas a new user will be sent directly to the community survey form. This new user does not get his/her account name and password until the form is filled out and sent to an administrator for authentication; once a community member has been authenticated, they are able to update their information, view certain maps, and add comments to a 'blog'. Two levels of access were created, one for captains and one for average residents.

The concept of a captain's map vs. neighborhood and community maps is that the more broadly accessible one, whether at the neighborhood or community level, will actually function as a Disaster Protocol map with gathering locations, instructions, and contacts, while protecting the display and distribution of more potentially sensitive information. Captains' access brings up links to 1.) a captain's neighborhood map that includes data that may be inappropriate to display on the resident map 2.) a "neighborhood roster", or printable document of everyone in the neighborhood by household as well as their special needs, skills, and resources, and 3.) a community map and roster. A box to the left of each entry would allow the captain to check who is on the list against who is accounted for and who might be missing after a disaster.

RESULTS

Our graphical user interface (GUI) creates an account for any verifiable Freshwater resident once they have completed the online form, at which point they have access to their neighborhood's and the community's Disaster Protocol maps. The Neighborhood maps utilize GIS functionality in emergency situations to assess needs (for instance, medical care that requires electricity), locate resources (i.e. generators), and prioritize decisions. The two-tiered, password-protected account access allows captains to update or enter information for residents who prefer paper forms, yet is simplistic in the online form. Print, Zoom, and Navigate buttons are built into the center of the page for ease of use, reflecting the Human-Computer Interaction design goals; future functionality for interactive and scroll-over data display is built in with the Info button; and the Annotate and Email button allows captains to share information with each other by commenting directly on the map and sending it as an .img file.

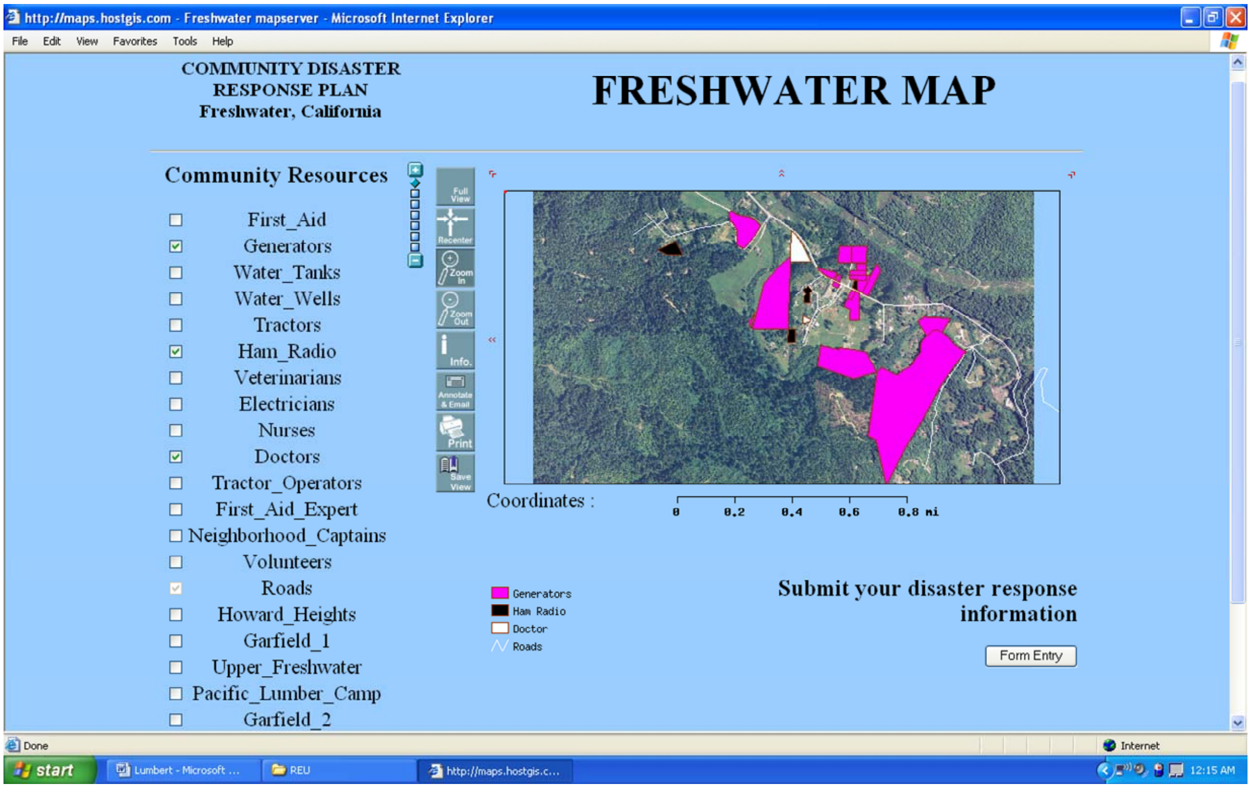

Figure 3. Screen shot of a community map displaying the most vital reports in a post-disaster scenario: generators, radios and doctors. Adobe Flash will be used to add interactive data access by parcel.

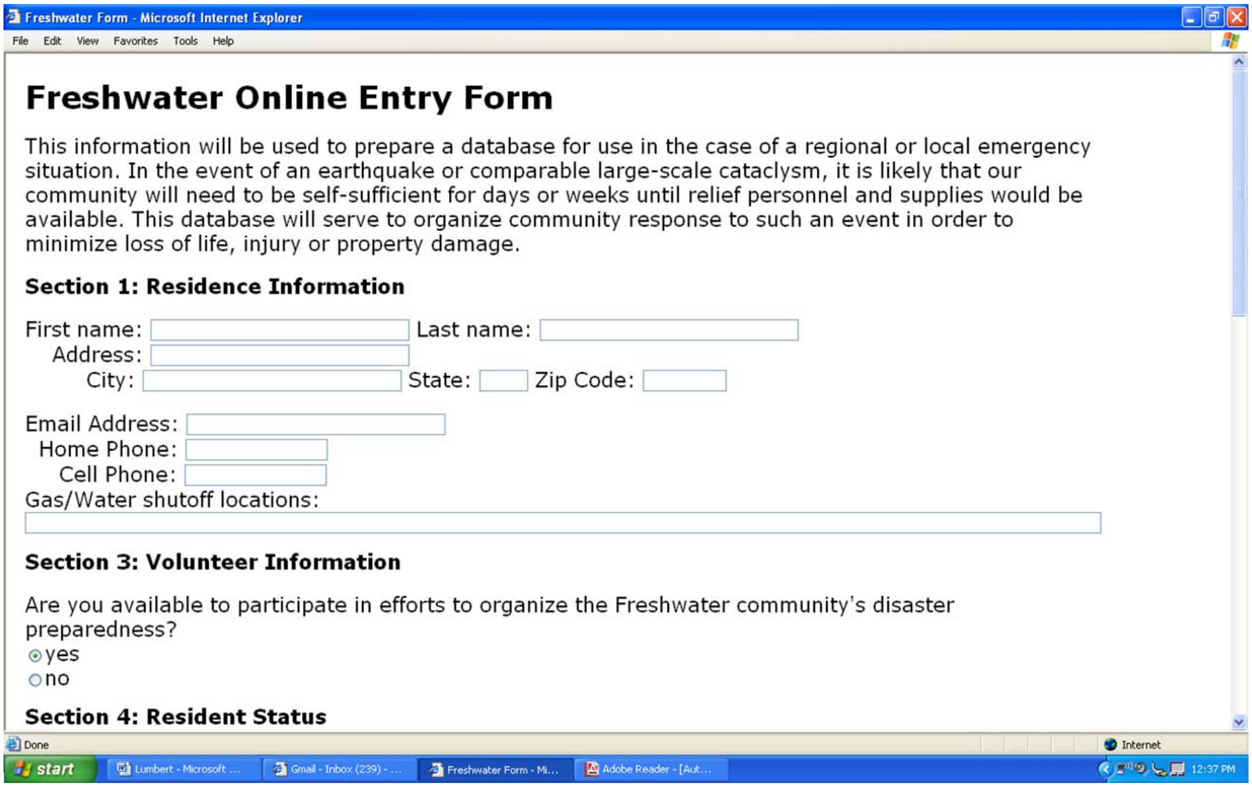

Figure 4. Screen shot of the online entry form residents (or captains) use to enter their information into the database. Upon completion, the above data will be included in query reports such as 'medical needs'.

DISCUSSION

Many aspects of GIS are incorporated into modern emergency management and response, particularly the use of remote sensing to detect and track hazards such as tornadoes, hurricanes, and fires (Barnes, 2004; Peduzzi et al., 2005). However, the immediate post-disaster user interface is thought by Cutter (2003) to be a critical area in GIS research. The immense potential of GIScience for emergency management is lost, she states, if first responders continue to experience difficulties with the technology. We focused on designing a platform that was easy enough for almost anyone in the community to use, yet contained enough information to be of genuine value.

Product requirements included a user-friendly GUI, password-protected database entry and manipulation, and easily printable hard copy maps and rosters. One problem discussed by community leaders was the reluctance of many community members to divulge information. Security concerns about information abuse, for example showing the locations of expensive equipment or displaying personal information, were addressed by creating tiered access--captain and resident--and carefully choosing the information to be requested in the online form.

Freshwater is exploring the concept of Neighborhood Response Teams as implemented in Taiwan, which could expand the usefulness of the Freshwater Disaster Plan and provide a more complete preparedness/first response prototype for other communities. With earthquakes the primary concern of the region, the physical terrain of Freshwater will soon be modeled in a GIS environment to create risk assessment maps at the neighborhood and community levels. Combined with inherently unstable geology, often excessively logged watersheds, and heavy seasonal rains, the results of a serious earthquake would vary based on slope, vegetation, underlying geomorphology, and other factors. Mapping the severity of risk beforehand is therefore invaluable for both planning and relief efforts.

CONCLUSION

The Freshwater model has enabled this rural area to optimize immediate post-disaster relief efforts through the networking of resident expertise, resources, and equipment. Although the Freshwater Community Disaster Response Plan is still in its infancy, its organizers are excited about taking direct steps to ensure the safety of their community in the absence of outside help. We hope that eventually the Freshwater model will be easily transferable to other communities of different sizes and needs, as the open-source platform removes the cost barrier while proper interface design reduces the need for highly trained personnel. The Freshwater model has the potential to fill an important role in emergency management, and its citizens should be acknowledged for taking a critical step towards community safety as the era of global warming begins.

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