Building a Low-Cost Geographic Website for Collecting Citizen Science Contributions

David A. Parr
Texas State University

Michael Scholz
Winona State University

In 2004, shortly after the introduction of Google Maps, Paul Rademacher created the first web mashup mapping housing data from Craigslist. Since then, web mapping has become ubiquitous on websites and mobile applications in many realms, including social networking, collaborative mapping, and citizen science. During this time, web mapping technologies have developed rapidly. A wide variety of new software from both private vendors and open source collaborators has made the barrier to entry for web mapping platforms relatively easy to overcome. Using this technology can assist geography researchers to collect information from citizen scientists. In this project, we explore different low-cost, low-barrier options of web technologies for citizen science websites. Using this information, we created a website to collect volunteered information about low water crossing hazards perceptions in central Texas. Choosing the right combination of software to implement a geographic citizen science project requires understanding the basics behind web portals. Web mapping portals are built on a GeoStack, or the layers of database and storage, data server, imagery server, and viewer that allow seamless integration of web portal technologies. We present the most popular open source software choices for each GeoStack layer and a comparison of the features for these products. For our project collecting low water crossing hazard information, we selected a combination of WordPress blogging software and a Google Maps plug-in called GeoMashup. The software allows users to submit possible low water crossings as point data in addition to descriptions and photos. Other users can comment and verify locations. A group of undergraduate students, some with geographic information system (GIS) experience and some without, tested the software for usability. The results indicate that the software is easy to use for most students regardless of GIS experience. Using such a portal should allow applied geography researchers to work with citizen scientists to collect photos and information about a wide variety of geographic phenomena. **Keywords: citizen science, flood hazards, GeoStack, hazard perception, volunteered geographic information (VGI), web portal.**

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In 2004, shortly after the introduction of Google Maps, Paul Rademacher created the first web mashup, or a website that uses content from multiple sources, to map housing data from Craigslist. Since then, mapping has become ubiquitous on websites and mobile applications for purposes including social networking and collaborative mapping. A wide variety of new software from both private vendors and open source collaborators has made implementing a web mapping platform relatively easy. Web mapping can assist geography researchers to both visualize and collect information from citizen scientists. A citizen science project allows any interested nonprofessionals to collect, analyze, and disseminate scientific data toward a collective goal (Newman *et al.* 2010; Haklay 2013). In this project, different low-cost, low-barrier options of web technologies for geographic citizen science websites are explored and an implementation is beta tested for usability.

The authors have developed a web mapping and data collection site for the Central Texas Low Water Crossings (CTLWC) project, a citizen science project encouraging amateurs to contribute information on low water crossings. A low water crossing is a "road stream-crossing structure designed to be overtopped by high flows" (Clarkin *et al.* 2006, ix). When water flow is high, the roadway becomes partially or fully submerged. There are more than 5,000 low water crossings in Texas (M. Luna personal comunication 2011). In central Texas between 1950 and 2004, more than 200 people died in accidents when vehicles met flooded roadways (Maples and Tiefenbacher 2009). Central Texas, which includes the area from Austin to San Antonio and much of the Texas Hill Country, had three of the top ten fastest growing cities in the United States in 2013 (U.S. Census Bureau 2014). The increase in population and the ephemeral nature of roadway flooding in central Texas might increase the danger of these hazards. The goal of the CTLWC is to use local citizens to participate in identifying potential hazardous roadways through a web mapping site.

Many technologies for building web mapping sites exist. Which software a researcher chooses is determined by the resources available and the requirements of the project. Resources include time, budget, available hardware, and the availability of expertise for design, implementation, and maintenance. Web mapping project requirements will vary from project to project. Common requirements consider the life span of the project and the type of interaction with the public, which might require user accounts and data security, particularly in the case of sensitive data. Other considerations include the amount, volume, and variety of data that will need to be stored and accessed;

data recovery considerations; and the devices (laptops, desktops, mobile devices) that will need access.

Geographic citizen science, or the use of nonprofessionals to collect and analyze research data, is nothing new (Haklay 2013). Early projects include the annual Audubon Christmas Bird Count beginning in the early twentieth century (Connors, Lei, and Kelly 2012). Nonprofessional geographers can submit volunteered geographic information (VGI) to websites in the form of status updates or map data, and they can contribute data toward a scientific goal (Turner 2006; Goodchild 2007). Recent web-based geographic citizen science projects include eBird.org, which collects bird sightings, and the California Roadkill Observation System, which tracks animal movements. Each website includes location information and related data.

The Geostack: Building a Web Map

Choosing the combination of software to implement a geographic citizen science project requires understanding the basics behind web mapping sites. Web mapping sites are built on a *GeoStack*, or the layers of database and storage, data server, imagery server, and viewer that allow seamless integration of Internet technologies. A stack is a collection of technologies designed to allow individual roles to run on open standards and be swapped interchangeably. The open source LAMP stack is the combination of Linux servers running Apache web servers with MySQL database servers and a programming language, generally PHP, Python, or perl (Ware and Lee 2002). The GeoStack is similar to the LAMP stack (Peterson 2014). Dividing the work of the web into stack layers does more than allow interchangeable components (Lawton 2005). Layers can be upgraded quickly because the entire system does not require replacement. Isolating data services from the web services provides added security and the flexibility of the stack structure allows greater reuse and faster development.

The GeoStack consists of four components: the data layer, the server layer, the imagery layer, and the client layer (Figure 1). A specific piece of software might handle one or more of these layers, but in general each layer is handled by a different server and software. In the distributed, cloud-based Internet, layers in the GeoStack can be handled by different servers from different companies in different parts of the world (Peterson 2014).

The *data layer* is responsible for storing, serving, and protecting the data. For security reasons, the data layer does not communicate directly with the client layer. Instead, the data layer, typically a database, serves data to the server layer. The server layer should optimally organize queries for data based on the requirement of the end user. In spatially aware databases, some geoprocessing functions might take place in the database.

The *server layer* sits between the data layer and the client layer. It controls access to the data layer and processes requests from the client layer. The server layer is also tightly coupled with the web server. The job of the server layer is to provide spatial data in a format that the client layer can quickly display. Some server software also supports services from the Open Geospatial Consortium (OGC), a consortium of companies and governmental organizations that designs and implements geospatial technology standards. These services include the Web Map Service (WMS) for serving map images or tiles; Web Feature Service (WFS) for serving vector features; Web Coverage Service (WCS) for serving coverage data; and Web Processing Service (WPS), which standardizes the ways that servers might apply spatial operations such as map overlay (OGC 2014).

In most web maps today, image tiles are used as background to provide fast navigation and rescaling for web browsers. The *imagery layer* provides these tiles. In the case of a slow connection speed, using tiles allows the client to load only the needed images. As a client shifts a map, new tiles can be loaded on demand. In the case of zooming in or out of a map, the imagery layer can provide new tiles at fixed scales. Tiles can be created in advance on the imagery server and cached on the client, which speeds up serving images. Serving tiles has a few drawbacks, however. Using tiles instead of traditional geographic information system (GIS) layers (vector or raster) does not allow the user to select specific layers for viewing. Tiles are generally created in only a handful of projections, which limits how the map data can be visualized to the end user. Web Mercator, a special projection popularized with Google Maps commonly used with map tiles, has many of the limitations of the Mercator projection with large distortion at the poles and is nonconformal (Battersby *et al.* 2014).

The *client layer* integrates the data and tiles from the server layer and the imagery layer. Typically, this runs within a web browser (*i.e.*, Mozilla Firefox or Google Chrome) but could also be embedded within a mobile device application or used by a desktop application such as ESRI ArcGIS Desktop 10.2.2 (2014, Environmental Systems Research Institute [ESRI], Redlands, California) or QGIS 2.8 (2014, the QGIS Project, an open source project released under the Creative Commons license) A web-based client layer processes and displays Hypertext Markup Language (HTML), and uses JavaScript to customize maps for interactive display. The JavaScript component is the key to integrating data from the different layers and allowing asynchronous, interactive communication to update a web map.

Current Software

In this section, a summary of current and popular open source or low-cost web mapping software options is provided. Open source software and data are free to use, free to modify, and free to redistribute under

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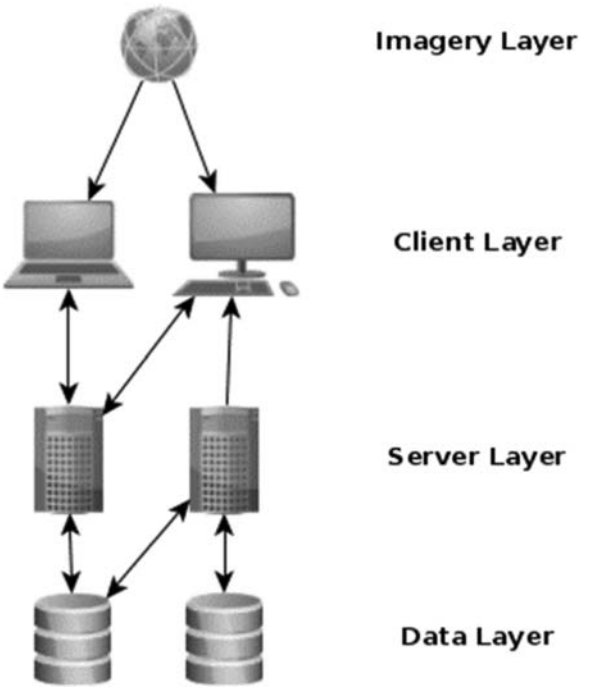


Figure 1 *Example GeoStack layer connectivity.*

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most conditions (Raymond 2001). Low-cost platforms are those that are free to use under most conditions but might come with restrictions in use, modification, or redistribution. New software appears with some frequency, particularly as new technologies and requirements evolve due to consumer demand and industry innovation. Readers in the distant future are thus suggested to consider new alternatives to those presented here.

Data Layer Software

When collecting data on the web, a relational database management system (RDBMS) can provide data integrity, quick access, and persistence between sessions. For these reasons, using a database to store persistent web information is the de facto standard. Many commercial database vendors provide spatial extensions for their database products. Oracle, Microsoft, and IBM all provide extensions on their database products for spatial data. These spatial extensions provide native support for spatial and geographic data for vector and in some cases raster, triangulated irregular network (TIN), or 3D data types. Spatial databases also allow spatial searches; geoprocessing and map overlay functions; and datum and projection transformations. The leading open source RDBMS with a spatial extension is PostgreSQL running the PostGIS extension. PostGIS supports exporting geographic data directly into most standard web formats. Supporting these common geographic data formats allows PostGIS to easily work with several popular server layer applications. Two other open source RDBMSs provide spatial extensions: MySQL and SQLite using the extension SpatiaLite.

Server Layer Software

The leading open source web-based mapping data server layer applications include GeoServer, MapServer, and deegree. ESRI's ArcGIS for Server provides server layer functions as a commercial application. GeoServer, MapServer, and deegree each support PostGIS, MySQL, or shapefiles as data layer services and can provide data in geographic markup language (GML), Keyhole markup language (KML), geographic JavaScript object notation (GeoJSON), or WFS. In addition to serving data, MapServer can generate on-the-fly clickable map images from multiple layers.

None of these software packages provide full web servers, however, and they require some integration into a web server environment. Integrating the map services into a content management system (CMS) provides a richer set of web data management. Open source CMSs such as WordPress, Drupal, or Joomla provide a consistent look and feel across a website and offer different levels of privilege in site administration for creating content. Each has a web mapping plug-in available. WordPress has Geo Mashup, which supports integration with OpenStreetMap or Google Maps tiles and allows customization of map style, size,

and interaction. The advantage of a CMS is that it makes setting up and editing web content easy, but the convenience might come at the cost of flexibility in the options that the mapping component can provide.

In the case where mapping services need to be tightly coupled with the web server, one option is to consider a high-level, rapid-development programming language framework. GeoDjango is a spatial extension of the Python-language web framework Django. GeoDjango supports a wide variety of spatial formats and connections to spatial databases. The large catalog of Python modules and application programming interfaces (APIs) allows GeoDjango-enabled programs to interact with virtually any other mapping program or web service. This option requires relatively strong programming skills but offers the most flexibility out of any server layer software option.

Imagery Layer Software

Many server layer applications support serving web map tiles, or the multiscale map images used in "slippy" maps online. Vendors (Google, Microsoft Bing, Yahoo!) also provide map tiles under restrictive licensing agreements, although for many purposes they are accessible for free up to a certain amount of use. Open source WMS providers (*e.g.*, OpenStreetMap) provide map tiles without restrictions commonly found from commercial vendors. Many U.S. federal government agencies, including the U.S. Census Bureau, the National Weather Service, and the National Aeronautics and Space Administration, provide their own WMSs that can be accessed freely. Other organizations also provide WMSs. The website Spatineo lists more than 450,000 available mapping services available currently (Spatineo 2014). Using Mapbox's open source Tilemill software allows for custom map tile generation.

Client Layer Software

In a web environment, the client layer is typically a JavaScript library (or set of libraries) that are loaded when a user accesses pages from a website in a web browser. The JavaScript controls the interactive display of the tiles and map data. Each commercial vendor (Google, Microsoft, Bing, Yahoo!) has its own set of JavaScript libraries. There are also a growing set of open source JavaScript mapping libraries. These include OpenLayers, Leaflet, and Mapbox.js. Each library can access information from a wide variety of sources (including, often, vendor-generated tiles) and also provides support for OGC's web mapping standards.

Methods and Implementation

The goal for this project was to implement a web mapping portal to allow volunteers to submit locations, descriptions, and photographs for low water crossings in Texas. The CTLWC Project was designed to allow citizens to submit and evaluate information to assist local and state agencies in identifying perceived road hazards.

For our project, the specific requirements for implementing a web portal included the following:

1. Users can submit locations, descriptions, and photographs.
2. Users should have authenticated logins. This allows us to communicate with them and helps to prevent erroneous or spam data.
3. Users should be able to comment on submissions.
4. Users should be able to select point locations on a map or enter a coordinate pair (latitude and longitude).
5. Submitted locations can be mapped individually or as a group.
6. Site visitors (noncontributors) may view map data but not edit, nor should one user have write access to another's information.
7. Site administrators should be able to export location information and control access to the site as needed.
8. The site should not require extensive GIS knowledge. GIS terminology should be avoided in favor of simplicity (Newman et al. 2010).

Based on these criteria, the solution chosen was to implement the WordPress CMS using the Geo Mashup plug-in with an OpenLayers interface to OpenStreetMap's tile services. This GeoStack met all of our requirements and was easy to install and administer. Figure 2 outlines the conceptual infrastructure of the website.

The website should be easy to use regardless of geographic background, spatial skills level, education level, academic major, or sex. A test group of forty undergraduate students submitted locations, descriptions, photos, and comments of low water crossings. Each student was given a written set of instructions that included how to add an account, how to add a location, how to comment on an entry, and how to add a photo. The students watched a twenty-minute video describing low water crossings and their effects in central Texas. Students had three weeks to complete an assignment of adding one or more locations and commenting on another person's entry. The students included one group from GIS courses who had more exposure to mapping and one group from a nonmajor introductory geography course who had not taken other geography courses. Table 1 provides details on the students in the study.

The sex, age, academic major, and number of geography courses taken were collected for each student by survey. Each student was given a spatial skills self-assessment and an evaluation of the website. Both of these were rated on a seven-point Likert scale ranging from 1 (*strongly agree*) to 7 (*strongly disagree*).

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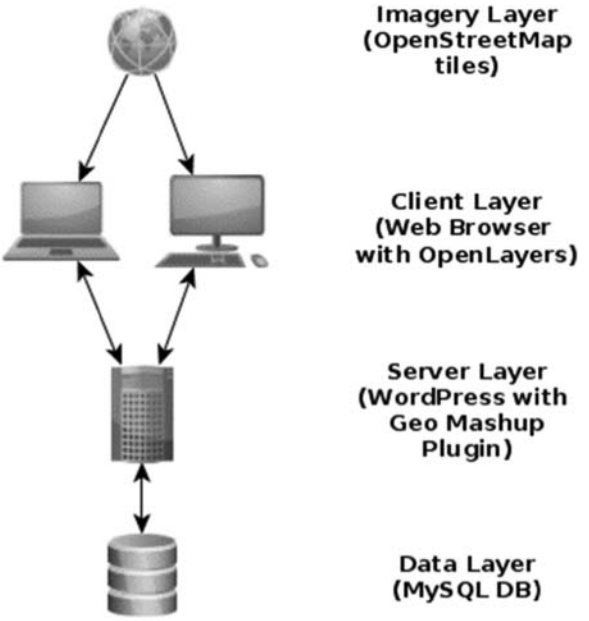


Figure 2 *The GeoStack used for this project.*

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The hypotheses used in this research is that there is no difference in how difficult students found the website to use based on sex, no difference in the number of geography courses taken, no difference in the self-assessed spatial skills, and no difference whether the student is a geography or nongeography major. To test, a Mann–Whitney U rank-sum test was run using cases for sex (male and female), number of geography classes taken (one or more than one), self-assessment for spatial skills (high or low), and for majors (geography or nongeography). Each case was compared against the first three statements from the website evaluation survey: "I had no difficulty using the website" (B1), "I had no difficulty entering data into the website" (B2), and "The website was easy to navigate" (B3). The remaining eight statements from the survey informed us where any difficulties with the website originated but were not used to consider the overall effectiveness of the website.

Table 1 *Description of students in website evaluation*

Major	**Count**	**Sex**	**Count**
Geography (Physical, Resource, GIS)	21	Male	23
Nongeography	12	Female	10
Not reported	7	Not reported	7
Level in school	**Count**	**Geography classes taken**	**Count**
First year	3	0 or 1 class	15
Sophomore	8	2 or more classes	21
Junior	10	Not reported	7
Senior	11		
Not reported	8		

Note: $N = 40$. GIS = geographic information systems.

Results

In Table 2, the results of the spatial skills self-assessment are listed. Questions A1, A3, A4, and A5 are positively related to spatial skills of direction, distance, and location. Questions A2 and A6 are negatively related to spatial memory and direction. The statements were chosen to develop on the spatial primitive concepts given in Golledge, Marsh, and Battersby (2008). The negatively related scores were inverted (a score of seven became one; a score of one became seven), and an average skill value was assessed for each student. Combining the spatial skills assessment scores, twenty-one students had "high" self-assessment scores above 3.5 on average and twelve students had "low" self-assessment scores below 3.5. Seven students did not take the skills self-assessment and were removed from the study.

In Table 3, the results of the evaluation of the website show that, in general, students found the website easy to use and navigate with the exception of uploading photos to the website. Questions B1, B2, and B3 are used to evaluate the usability of the website.

The results show that for all but three cases, there was no significant difference in how participants perceived the difficulty of the website when considering sex, number of geography classes, self-assessed spatial skills, or academic major. For Statement B1, "I had no difficulty using the website," there was a significant difference (p value $< .05$) between students with high and low values in the

Table 2 *Results of spatial skills self-assessment*

Indicate your level of agreement with this statement. (1 = strongly agree, 7 = strongly disagree)	Median	Mode	Agree or strongly agree (1 or 2)	Neutral (3, 4, or 5)	Disagree or strongly disagree (6 or 7)
A1. I am very good at giving directions.	3	3	12 (36.4%)	19 (57.6%)	2 (6.1%)
A2. I have a poor memory for where I left things.	5	5	4 (12.1%)	20 (60.6%)	9 (27.3%)
A3. I am very good at judging distances.	3	2	12 (36.4%)	20 (60.6%)	1 (3%)
A4. My "sense of direction" is very good.	2	1	18 (54.5%)	10 (30.3%)	5 (15.2%)
A5. I tend to think of my environment in terms of cardinal directions (N, S, E, W)	4	4	12 (36.4%)	16 (48.5%)	5 (15.2%)
A6. I very easily get lost in a new city.	5	5	7 (21.2%)	16 (48.5%)	10 (30.3%)

Note: $N = 33$.

Table 3 *Results of website evaluation survey*

Indicate your level of agreement with this statement. (1 = strongly agree, 7 = strongly disagree)	Median	Mode	Agree or strongly agree (1 or 2)	Neutral (3, 4, or 5)	Disagree or strongly disagree (6 or 7)
B1. I had no difficulty using the website.	2	2	24 (72.7%)	6 (18.2%)	3 (9.1%)
B2. I had no difficulty entering data into the website.	2	1	26 (78.8%)	5 (15.2%)	2 (6.1%)
B3. The website is easy to navigate.	2	1	23 (69.7%)	8 (24.2%)	2 (6.1%)
B4. I could find what I wanted quickly.	2	1	23 (69.7%)	9 (27.3%)	1 (3%)
B5. I had no difficulty choosing a low water crossing location.	2	1	19 (57.6%)	12 (36.4%)	2 (6.1%)
B6. I had no difficulty reading the map.	1	1	29 (87.9%)	2 (6.1%)	2 (6.1%)
B7. I had no difficulty commenting on others' choices.	1	1	24 (72.7%)	9 (27.3%)	0 (0%)
B8. I understood the website's directions clearly.	1	1	28 (84.8%)	4 (12.1%)	1 (3%)
B9. I understand low water crossings better from using the website.	3	4	12 (36.4%)	19 (57.6%)	2 (6.1%)
B10. I understand how my contribution is useful to the community.	2	1	24 (72.7%)	8 (24.2%)	1 (3%)
B11. I found uploading a photo easy on the website.	4	4	12 (36.4%)	20 (60.6%)	1 (3%)

Note: $N = 33$.

Table 4 *Results of Mann–Whitney U test*

Indicate your level of agreement with this statement	Case	Count	*M*	Mann–Whitney U	*p* value two-sided
B1. I had no difficulty using the website. (1 = strongly agree, 7 = strongly disagree)	Sex: Male	20	2.3	141.5	0.6697
	Sex: Female	13	2.5		
	Geography classes: 0 or 1	14	3.1	166	0.2128
	Geography classes: 2 or more	19	1.8		
	High self-assessment spatial skills	21	2.0	72	.03511**
	Low self-assessment spatial skills	12	3.1		
	Nongeography major	12	3.5	64.5	.03582**
	Geography major	19	1.7		
B2. I had no difficulty entering data into the website. (1 = strongly agree, 7 = strongly disagree)	Sex: Male	20	1.8	164.5	0.1762
	Sex: Female	13	2.3		
	Geography classes: 1	14	2.4	157	0.3554
	Geography classes: 2 or more	19	1.7		
	High self-assessment spatial skills	21	1.9	81	.07216*
	Low self-assessment spatial skills	12	2.2		
	Nongeography major	12	2.7	81	0.1585
	Geography major	19	1.7		
B3. The website is easy to navigate. (1 = strongly agree, 7 = strongly disagree)	Sex: Male	20	2.3	130.5	1
	Sex: Female	13	1.9		
	Geography classes: 0 or 1	14	2.4	135	0.9539
	Geography classes: 2 or more	19	2.0		
	High self-assessment spatial skills	21	2.0	97.5	0.2854
	Low self-assessment spatial skills	12	2.4		
	Nongeography major	12	2.7	82	0.176
	Geography major	19	1.7		

Note: $N = 33$.
*$p < .1$.
**$p < .05$.

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self-assessment spatial skills and between geography and nongeography majors. On Statement B2, "I had no difficulty entering data into the website," there was a significant difference (p value $< .1$) between students who had low and high self-assessed spatial skill sets. There was no significant difference between cases when determining the difficulty with using the website or entering data. The results of the Mann–Whitney U test are listed in Table 4.

Conclusions

In the open response section of the survey, students reported mostly positive experiences with the website ("It was fun"), but much of the frustration came from working with the maps and uploading photographs. It was unclear to a few students how to select low water crossings. Students with more geography classes might understand the concepts better, which could explain why there was a difference between geography and nongeography majors and between high and low self-assessed spatial skill sets. Some subjects appreciated the participatory aspect of the website and the contribution made to their community.

This study suggests that usability considerations of a geographic citizen science website are necessary for successful deployment. A lack of familiarity with geographic concepts or comfort in spatial skills presents problems for the successful adoption of a mapping website. Evidence from the students' comments suggests that engagement in a citizen science project is rewarding.

The options for web mapping software have increased dramatically in the past ten years. The barriers to building a usable, low-cost citizen science web mapping website have also decreased as more open source and low-cost options have emerged (Sui 2014). A single platform with all of the necessary characteristics for a flexible, geographic citizen science website has not yet been built. Topics for a mapping citizen science website might include hazard perceptions, species identification and tracking, environmental pollutant tracking, identifying issues in urban areas, or transportation issues. Previous work has outlined some of the considerations a project like this would require (Newman et al. 2010). Creating a flexible yet simple web mapping portal is a challenge with great potential.

References

Battersby, S., M. Finn, L. Usery, and K. Yamamoto. 2014. Implementations of Web Mercator and its use in online mapping. *Cartographica: The International Journal for Geographic Information and Geovisualization*, 49 (2):86.

Clarkin, K., G. Keller, T. Warhol, and S. Hixson. 2006. *Low-water crossings: Geomorphic, biological, and engineering design considerations*. San Dimas, CA: United States Department of Agriculture Forest Service National Technology and Development Program.

Connors, J. P., S. Lei, and M. Kelly. 2012. Citizen science in the age of neogeography: Utilizing volunteered geographic information for environmental monitoring. *Annals of the Association of American Geographers*, 102 (6): 1267–1289.

Golledge, R. G., M. Marsh, and S. Battersby. 2008. Matching geospatial concepts with geographic educational needs. *Geographical Research*, 46 (1): 85–98.

Goodchild, M. F. 2007. Citizens as voluntary sensors: Spatial data infrastructure in the world of Web 2.0. *International Journal of Spatial Data Infrastructure*, 2:24–32.

Haklay, M. 2013. Citizen science and volunteered geographic information: Overview and typology of participation. In *Crowdsourcing geographic information: Volunteered geographic information (VGI) in theory and practice*, ed. D. Z. Sui, S. Elwood, and M. F. Goodchild, 105–22. Dordrecht, Germany: Springer.

Lawton, G. 2005. LAMP lights enterprise development efforts. *IEEE Computer*, 38 (9): 18–20.

Maples, L. Z., and J. P. Tiefenbacher. 2009. Landscape, development, technology and drivers: The geography of drownings associated with automobiles in Texas floods, 1950–2004. *Applied Geography*, 29 (2): 224–34.

Newman, G., D. Zimmerman, A. Crall, M. Laituri, J. Graham, and L. Stapel. 2010. User-friendly web mapping: Lessons from a citizen science website. *International Journal of Geographical Information Science*, 24 (12): 1851–69.

Open Geospatial Consortium (OGC). 2014. OGC® standards and supporting documents. http://www.opengeospatial.org/standards/. Accessed April 15, 2014.

Peterson, M. 2014. *Mapping in the cloud*. New York: Guilford.

Raymond, E. S. 2001. *The cathedral and the bazaar*. Sebastopol, CA: O'Reilly Media.

Spatineo. 2014. Spatineo directory. http://www.spatineo.com/. Accessed April 14, 2014).

Sui, D. 2014. Opportunities and impediments for open GIS. *Transactions in GIS*, 18 (1): 1–24.

Turner, A. J. 2006. *Introduction to neogeography*. Sebastopol, CA: O'Reilly Media.

U.S. Census Bureau. 2014. South, West have fastest-growing cities, Census Bureau reports; Three of top 10 are in Texas capital area. Washington, DC: Census Bureau Newsroom. http://www.census.gov/newsroom/releases/archives/population/cb14-89.html. Accessed May 22, 2014.

Ware, J., and B. Lee. 2002. *Open source development with LAMP: Using Linux, Apache, MySQL and PHP*. Reading, MA: Addison-Wesley.

DAVID A. PARR is in the Department of Geography, Texas State University, 601 University Drive, San Marcos, TX 78666. E-mail: david.parr.geo@gmail.com. His research interests include volunteered geographic information, GIScience, collaboration, and spatial cognition and spatial learning.

MICHAEL SCHOLZ is the Coordinator of the Program of Geography, Winona State University, 175 West Mark Street, Winona, MN 55987. E-mail: mscholz@winona.edu. His research interests include spatial thinking, AP Human Geography, and Curriculum and Instruction.

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