CSU Geospatial Review
GEOGRAPHIC INFORMATION SCIENCE IN THE CALIFORNIA STATE UNIVERSITY SYSTEM VOLUME 14 • SPRING 2017

*Channel Islands*

# Establishing Sea Cliff Erosion Rates and Identifying Erosional Hotspots for Bechers Bay, Santa Rosa Island

**Figure 1:** A recent cliff failure along Bechers Bay on Santa Rosa Island.

Coastal bluffs or sea cliffs are steep sloping surfaces where uplifted land connects to coastlines. About 80% of the world's shorelines are coastal cliffs and are impacted by terrestrial and nearshore processes including rainfall runoff, wave impact, tidal range, and slope failure. Unlike beach erosion, which is often temporary or reversible, the landward retreat of sea cliffs results in the permanent removal of adjacent land. Sea cliff erosion, or retreat, can be a slow, persistent process; but more often, it is a result of a few large block failures (Figure 1) over an extended time period.

Bechers Bay littoral cell, extending 12 km on the northeastern side of Santa Rosa Island from Carrington Point to Skunk Point, is a relatively protected bay with predominantly mild wave action. Approximately 83% of this cell, or 10 km, is backed by actively eroding bluffs and steep, rocky cliffs punctuated by sand and

*continued on page 6*

INSIDE



**SAVE THE DATE**
Please join us at the 2017 ESRI International User Conference in San Diego, California, July 10–14.

## The Sanctity of Public Data

GIS researchers know the value of public data, but we often take it for granted. Raw, empirical evidence is the backbone that supports the GIS theory we use to help improve our research, our community, and our environment. GIS students who first take on the task of developing a semester project may find that navigating their way through Census, NOAA, NASA, USGS, or EPA data can be perplexing. However, we may have one of the best systems of freely available public data on the planet, as one quickly discovers when searching for data elsewhere. We are entering a period of uncertainty with the new federal administration's aims to downsize several important governmental branches, possibly threatening our system of free public data. Those of us who have been at this a while may remember the bad old days when accessing public data or finding a way to pay for it was a major barrier. I can remember when formerly free Landsat data was suddenly subjected to new charges under the Reagan administration, making it only affordable to oil companies and those with major grants. Our California colleagues at UC Berkeley recently held a volunteer-led data-archiving weekend to "rescue" NASA's earth science data. The intention was to protect the climate data needed to inform important decisions about the future of energy, the environment, and allocation of resources. Many of our CSU specialists do applied research connecting with local, state, and federal agencies, so maintaining those connections and considering ways to preserve public data may be something we can help with. If nothing else, we all should certainly continue to promote and teach about the merits of maintaining quality, long-term datasets for understanding our planet and its critical environmental systems.

Jerry Davis, *Director,* CSU GIS Specialty Center
San Francisco State University



*Northridge*

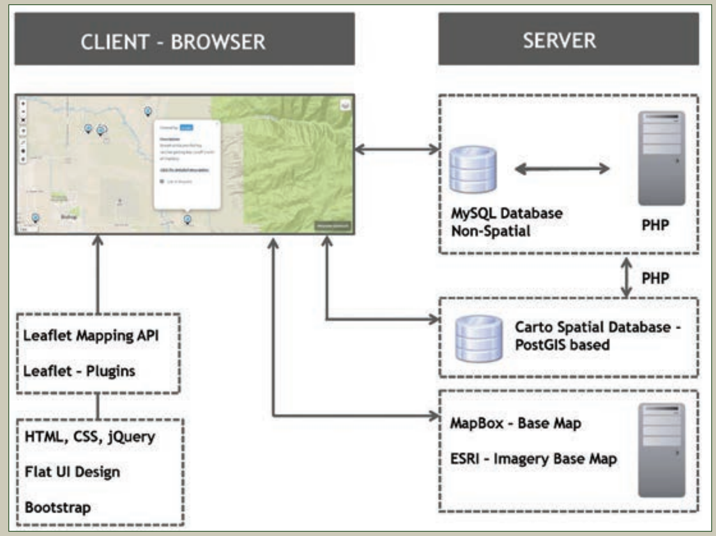



**Figure 1:** System Architecture of ParticipatoryGIS.com

# Implementing a Collaborative Web-based GIS

In 2013, Dr. Kimberly Kirner from California State University Northridge (CSUN) was awarded an NSF Coupled Natural and Human Systems (NSF-CNH) Program Exploratory Grant for the project "Coping with Change: Water Availability and Rangeland Management in the Eastern Sierra." In this interdisciplinary project, Dr. Kirner (PI, Anthropology) worked with Dr. James Hayes (Co-PI, Geography, U of Nebraska Omaha), Dr. Soheil Boroushaki (Geography, CSUN), and Dr. Paula Schiffman (Biology, CSUN) to investigate the impact of climate change and water policy on water availability, native plant communities, and local management responses in the Eastern Sierra. Studying the effects of changes in water availability on arid lands and key stakeholder groups has been challenging due to the impact that both climate change and water policy have at various scales, including federal, state, regional and local. At each scale, individuals perceive the changes differently and respond in unique ways shaped by cultural and institutional influences. This project examines how various stakeholder groups at different scales perceive climate and water policy changes over space and how these affect the resource base and management decisions. Accordingly, one main objective of this project is to better understand the changes in water availability over time, due to changes in weather patterns and water-use policies. More importantly, this project aims to determine and document how local communities have perceived and reacted to these changes over time and space using a Web-based system for collection and dissemination of spatial data.

Capturing the perception of the local communities over the changes of water availability and accessibility is aligned with the current trend towards the democratization of spatial decision and policy making procedures that requires direct involvement of the general public that is affected by spatial decision outcomes. It is in this context that local communities are increasingly seeking greater public participation in shaping spatial policy decisions. Moreover, the sustainability

*continue on next page*

of community development projects relies heavily on the integration of local spatial knowledge as supplemented by the scientific input of experts in the decision and policy making process. Increasing interest in the Web-based methods for participatory GIS (PGIS) and related technologies facilitates and emphasizes community involvement in the production and/or use of geographical information. PGIS enables a collaborative approach for community planning in which local people and planning authorities and experts exchange ideas, spatial information and perceptions (Rinner et al., 2008; Jankowski, 2009; Boroushaki and Malczewski 2010).

To address these challenges within the context of the NSF project, Dr. Boroushaki developed and designed a conceptual framework for a collaborative Web-based mapping and GIS, which consists of a main component based on the concept of Argumentation Maps that supports geographically referenced discussions in GIS by providing visual access to public geo-referenced debates (Rinner, 2001). The framework has been implemented within the ParticipatoryGIS.com domain. The Web application enables users to create, edit and store geospatial information and supports deliberation in a forum-like environment over water related geospatial data using the Argumentation Maps concept. The Web application enables different stakeholders to document their perceived environmental changes over the geospatial scale of the analysis.

ParticipatoryGIS.com uses the server-side architecture approach to Web-based GIS. It employs HTML, CSS, and JavaScript on the client-side and a combination of PHP and a MySQL database on the ParticipatoryGIS.com server and a PostGIS geodatabase using the Carto mapping service. The open-source Leaflet JavaScript library provides the interactive mapping functionalities. Two base maps are provided in ParticipatoryGIS.com, a thematic base map provided by MapBox mapping service and an imagery base map provided by ESRI. The preliminary testing and data creation phase is completed and the system will soon be open to local communities.

**ACKNOWLEDGMENT**

This material is based upon work supported by the National Science Foundation under Grant Number 1313656.

**REFERENCES**

Boroushaki, S., and J. Malczewski. 2010. Measuring consensus for collaborative decision-making: A GIS-based approach. *Computers, Environment and Urban Systems,* 34(4): 322-332.

Jankowski, P. 2009. Towards participatory geographical information systems for community-based environmental decision making. *Journal of Environmental Management,* 90(6): 1966-1971.

Rinner, C. 2001. Argumentation maps: GIS-based discussion support for online planning. *Environment and Planning B: Planning and Design.* 28 (6): 847–863.

Rinner, C., Keßler, C., and S. Andrulis. 2008. The use of Web 2.0 concepts to support deliberation in spatial decision-making. *Computers, Environment and Urban Systems.* 32(5): 386-395.

**AUTHORS**

*Soheil Boroushaki*
*Assistant Professor, Department of Geography*
*California State University, Northridge*
*soheil.boroushaki@csun.edu*

*Kimberly Kirner*
*Associate Professor, Department of Anthropology*
*California State University, Northridge*
*kkirner@csun.edu*

*James Hayes*
*Assistant Professor, Department of Geography and Geology*
*University of Nebraska, Omaha*
*jjhayes@unomaha.edu*

*San Jose*

**Figure 1:** Students Kirby Kiefer and Alex Shmurakov, flying a drone in the field to collect photographic data along the Sierra Nevada range front during a field trip in Active Tectonics at SJSU.

# Teaching Photogrammetry and Agisoft in the Classroom to Assess Earthquake Hazard

Through the incorporation of active learning strategies in a geology undergraduate class, students gained hands-on experiences with cutting-edge technology and scientific applications. Active learning can be defined as an instructional method that engages students through the learning process (Prince, 2004). Active learning strategies engage students, allow for skill development, and involve performance at higher order thinking levels (Bonwell & Eison, 1991). Here we describe how undergraduate geology students built upon their geologic and geomorphic knowledge with photogrammetry, Agisoft, and ArcMap to assess earthquake hazards in a region.

Students enrolled in Active Tectonics at San Jose State University applied a technique called Structure-from-Motion, where a drone is used to take overlapping photos to construct high-resolution digital topography data in the x, y, and z orientation along the escarpment of the Sierra Nevada Mountains (Figure 1). The digital topography data were then exported to ArcGIS to construct displacement

*continued on page 10*

# Water Mains Integrity Management Using Hot Spot Analysis

California's water infrastructure requires significant operational and managerial responsibilities associated with safeguarding public health. To help meet these complex water-related challenges, California Water Service Company (Cal Water) is developing a new Water Mains Integrity Management Program. The specific objectives of this program are to: i) achieve low life cycle cost (affordability), ii) quantify and manage risk, iii) renew the infrastructure, and iv) deliver excellent service to customers. Cal Water has been maintaining a detailed GIS database including reported pipe failure locations and times. Here we report results of a Hot Spot Analysis to identify high-risk pipe failure zones in five selected service areas in California: Bakersfield, Visalia, Stockton, Palos Verdes, and Bear Gulch (Figure 1). The study sites were selected based on the failure frequency and the presence of older pipe materials. Hot Spot Analysis was performed to identify trends in the clustering of water main failure densities within the defined space time cube




**Figure 1:** Study locations in California

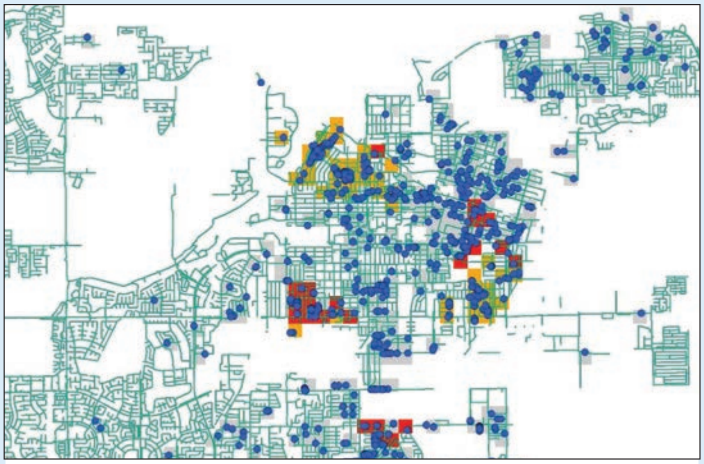
The results for each of the five service areas are shown in Figure 2. Bear Gulch and Stockton exhibited a higher number of Hot Spots. This might be due to the age of the material and the density of failures in some areas. In Palos Verdes and Visalia, the water mains were installed more recently and the number of failures is consequently lower. The Hot Spot Analysis tool provided several categories with which to define the trend. The most common case was "Not Emerging," which indicates that the resultant z-scores and p-values did not show any significant clustering behavior to enable classification as either a Hot or Cold Spot. The second most common case was "New Hot Spot," which indicates that an unusually high value of "z" was detected and that an underlying process had begun to cause problems in that area. The next category was "Oscillating Hot Spot", where in the most recent time step it was classified as a significant Hot Spot, but in the past, it had been categorized as a cold spot because it contained an unusually low number of failures. This analysis demonstrates that the Hot Spot analysis tool can help identify underlying process causing more failures.

This is currently a work in progress and more comprehensive results will be reported at a later date once it becomes possible to assess the overall success of the project. The authors believe that GIS analytical modeling will help lay the foundation for a standardized platform of sustainable life cycle assessments of the water infrastructure.

**AUTHORS**
*Diego Martínez García, Sathya Geetha Ganesan, and Juneseok Lee**
*Department of Civil and Environmental Engineering*
*San Jose State University*

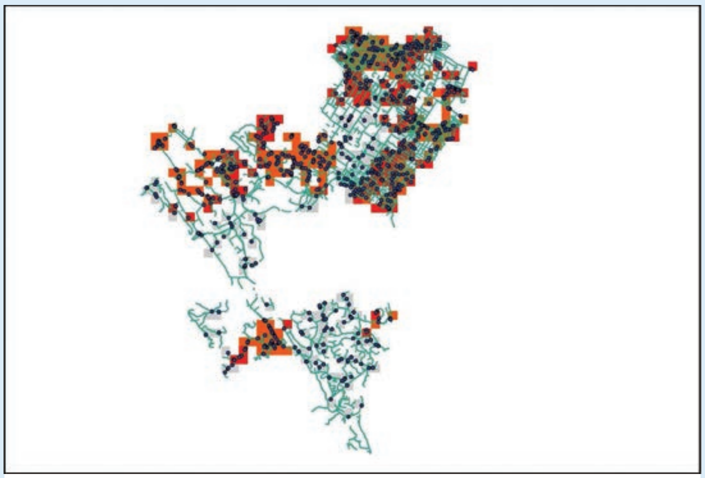
*Jonathan Keck and Paul Yang*
*California Water Service Company*
*1720 North First St., San José, CA 95112*

**Corresponding author email: Juneseok.lee@sjsu.edu*



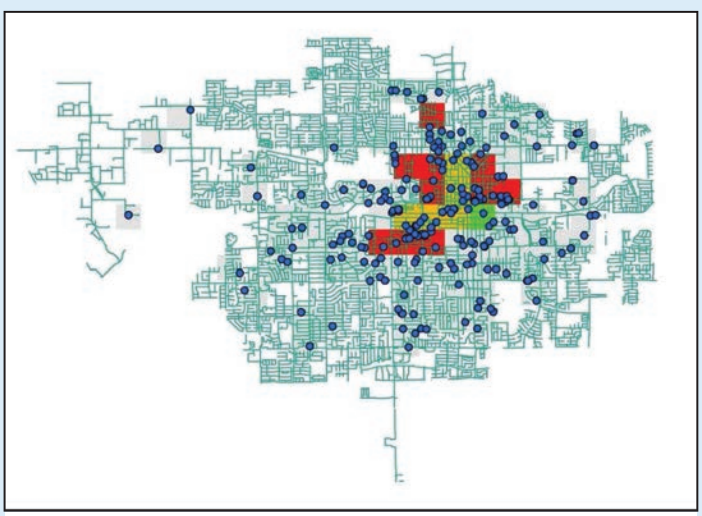
**Bakersfield**

| | |
|---|---|
| Consecutive Hot Spot | 39 bins |
| New Hot Spot | 23 bins |
| Not emerging | 231 bins |



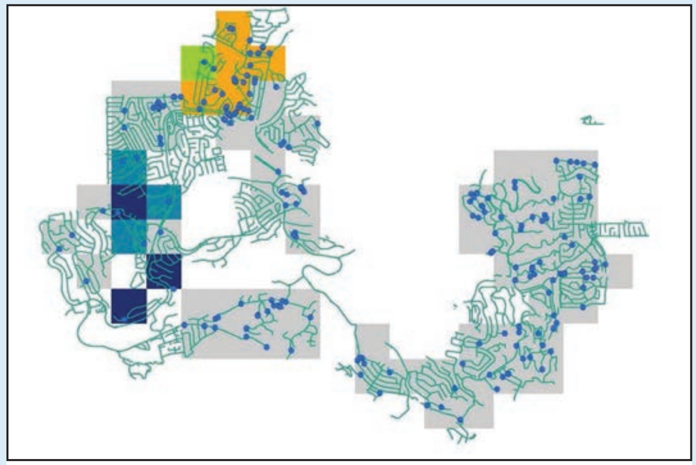
**Bear Gulch**

| | |
|---|---|
| New Hot Spot | 108 bins |
| Not Emerging | 107 bins |
| Oscillating | 125 bins |



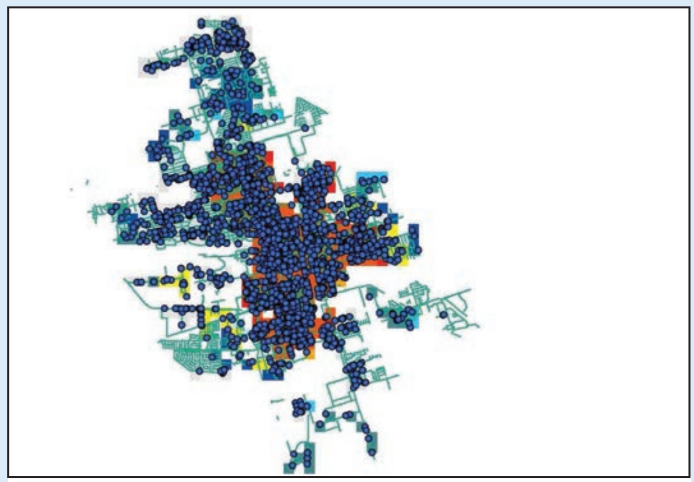
**Visalia**

| | |
|---|---|
| Sporadic Hot Spot | 1 bin |
| Consecutive Hot Spot | 5 bins |
| New Hot Spot | 10 bins |
| Not Emerging | 66 bins |



**Palos Verdes**

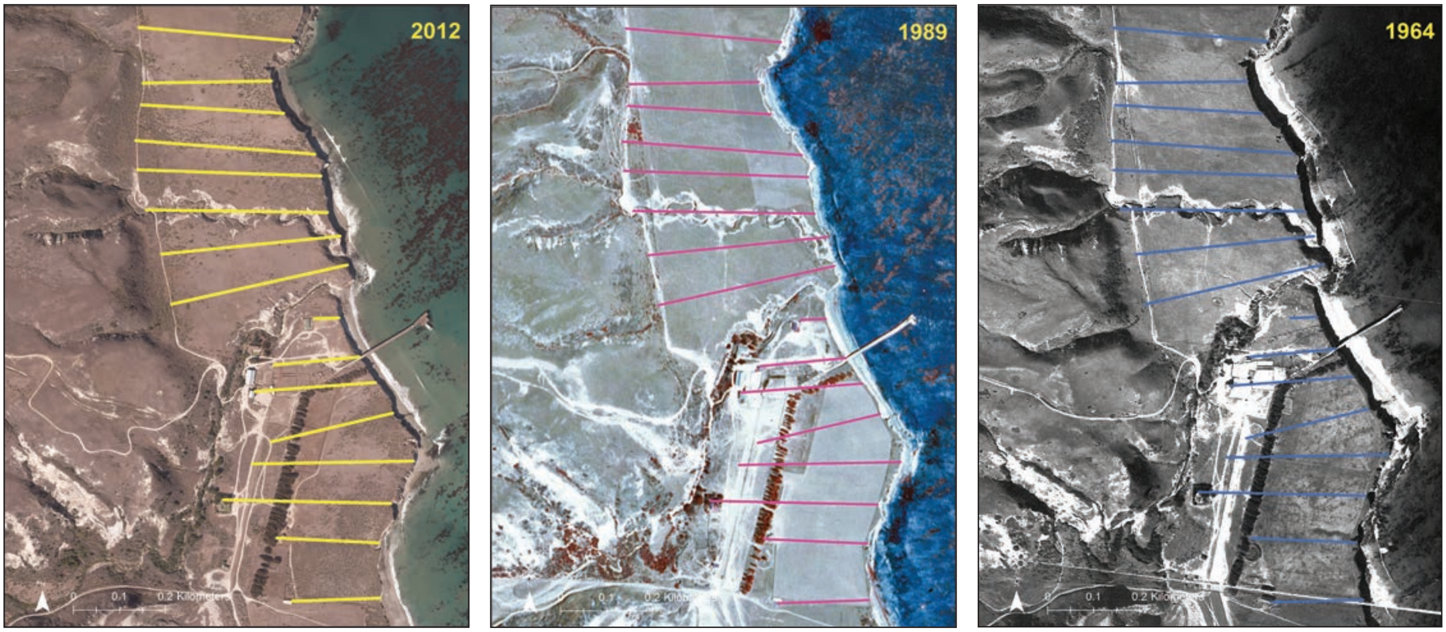
| | |
|---|---|
| Consecutive Cold Spot | 3 bins |
| Consecutive Hot Spot | 5 bins |
| New Cold Spot | 3 bins |
| Not Emerging | 53 bins |



**Stockton**

| | |
|---|---|
| Consecutive Cold Spot | 30 bins |
| Consecutive Hot Spot | 3 bins |
| Historical Hot Spot | 6 bins |
| New Hot Spot | 23 bins |
| Not Emerging | 142 bins |
| Oscillating Hot Spot | 148 bins |
| Persistent Cold Spot | 26 bins |
| Sporadic Cold Spot | 11 bins |
| Intensifying Cold Spot | 42 bins |

**Figure 2:** Results from the Emerging Hot Spot Analysis for five service areas. Water main failures (1986–present) are indicated with blue circles.



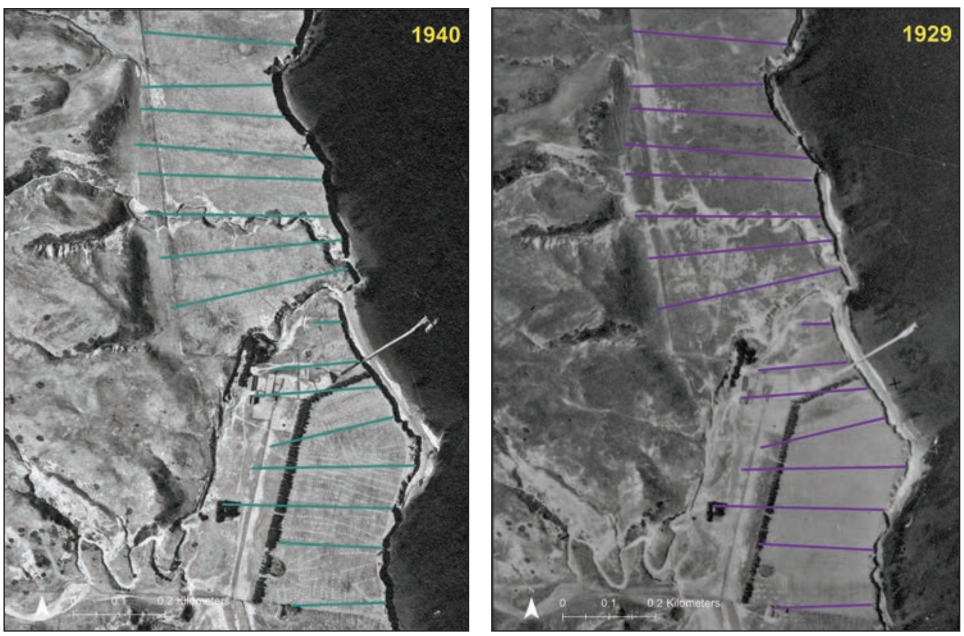




**Figure 2:** Aerial Photo Sequence

cobble beaches. As Santa Rosa Island is home to numerous archaeologically sensitive sites, understanding the vulnerability of the sea cliffs to erosion can improve the way the National Park manages cultural resources that may be exposed or lost if a large block failure occurs (Dibblee et al. 1998 and Schumann et al. 2014).

Using georectified historical imagery from 1929, 1940, 1964, and 1989 as well as satellite imagery from 2012, long-term sea cliff erosion rates were established. In addition, structure-from-motion (SfM) photogrammetry with surveyed ground control points were utilized to develop topographic point clouds of the sea cliffs in the study area to establish a baseline to observe storm-scale erosion. This kind of erosion is difficult to identify and quantify from nadir aerial photographs as it often takes place at the base or underneath overhanging portions of the sea cliff (Cruz de Oliveira et. al. 2004). By modeling the cliff faces along Bechers Bay, we can predict where these episodes of failure are likely to happen, thus identifying erosional hotspots, which is important for safety as well as cultural resource management.

Three techniques were utilized to quantify sea cliff retreat along Bechers Bay: historic aerial photograph analysis (Figure 2); digital photogrammetry using SfM; and LiDAR point cloud generation. SfM and LiDAR were utilized to create precise 3D models of the cliff face that can be compared over time to detect small-scale erosional features.

Using satellite imagery from 2012, 130 transects were recorded in a GIS environment that are consistent and comparable in the available historic georectified images from 1929, 1940, 1964, and 1984 (Runyan 2003). Transects were chosen at points that won't change over time and were visible in all the photographs like the corner of a house or a bend in a road. The distance from this feature to the cliff edge is measured and compared through time (Figure 3). To create a 3D model of the bluff along Becher's Bay, approximately 2,000 photos were taken with a GPS enabled camera, ensuring a 70% vertical and horizontal overlap of images. Images were processed using Pix4D software to create an ortho-mosaic image, 3D point cloud, and textured 3D mesh model. To gain more precision in the 3D point cloud, the cliff face was scanned using a terrestrial LiDAR and GPS unit. Once the point cloud was extracted from the LiDAR data, it was used with Pix4D to generate a 3D model of the cliffs with a sub-centimeter resolution.

Comparing historic imagery from 1929, 1940, 1964, and 1989 with satellite imagery taken in 2012, sea cliff erosion rates calculated from 130 transects along Bechers Bay were found to range from 0-51 cm per year throughout the cell for the 83 year time span from 1929-2012 (shown in Figure 3).

While reported as cm/year, erosion happens episodically. Because erosion rates were taken from aerial images, we could not identify erosional "hotspots" due to undercutting of the cliffs. Using LiDAR data and structure-from-motion photogrammetry, a precise model of the present cliff face was developed. This model will serve as baseline data to monitor storm-scale erosion of the bluffs and identify erosional hotspots and hazard zones. With the established point-cloud based model, we can overlay future data to detect small-scale erosion along Bechers Bay sea cliffs and predict the location of potential block failures.


**REFERENCES**

Cruz de Oliveira, S., Catalao, J., Ferreira, O., Alveirinho Dias, J.M. 2008. Evaluation of cliff retreat and beach nourishment in southern Portugal using photogrammetric techniques. *Journal of Coastal Research* 24(4A): 184-193.

Dibblee, Jr. T.W. and H.E. Ehrenspeck. 1998. Geology of Santa Rosa Island, California. UC Santa Barbara, Department of Geological Sciences.

Hapke, C.H. 2004. The measurement and interpretation of coastal cliff and bluff retreat: *U.S. Geological Survey Professional Paper* 1693: 39-50.

Runyan, K. and G. Griggs. 2003. The effects of armoring seacliffs on the natural sand supply to the beaches of California. *Journal of Coastal Research* 19(2): 336-347.

Schumann, R., Minor, S., Muhs, D., Pigati, J. 2014. Landscapes of Santa Rosa Island, Channel Islands National Park, California. In: *Monographs of the Western North American Naturalist.* Brigham Young University Press, 7(1): 48-67.



**AUTHORS**

*Kiki Patsch*
*Assistant Professor, Environmental Science and Resource Management*
*California State University, Channel Islands*
*kiki.patsch@csuci.edu*

*Aspen Coty*
*Undergraduate student, Environmental Science and Resource Management*
*California State University, Channel Islands*
*aspen.coty015@myci.csuci.edu*

*Patrick Costa*
*Undergraduate student, Environmental Science and Resource Management*
*California State University, Channel Islands*
*patrick.costa280@myci.csuci.edu*

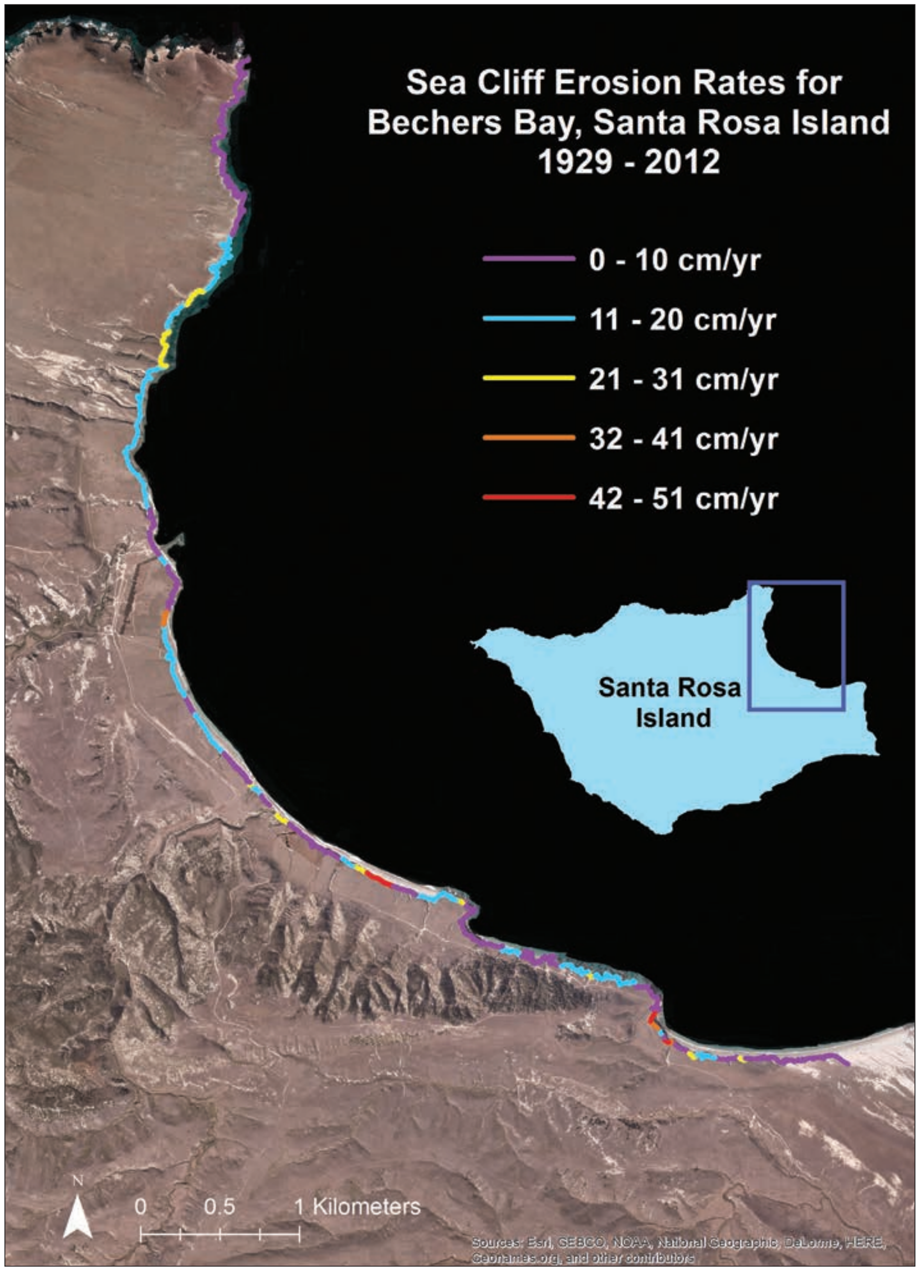




**Figure 3:** Sea Cliff Erosion Rates

# A Brief View of Colombia's Referendum on the FARC Peace Agreement: The Urban-rural Divide

On October 2, 2016, the Colombian electorate were presented with a single question—"Do you support the final agreement for ending the conflict and building a stable and lasting peace?" Surprisingly, they voted no. The peace agreement, negotiated by the government and formally signed on September 26, 2016, would have ended a 52-year armed conflict with the Fuerzas Armadas Revolucionarias Colombianas (FARC), a guerrilla movement. The FARC was founded in the 1960s by a small group of farmers under a Marxist-Leninist ideological model to fight against staggering levels of inequality in Colombia (BBC, 2016). FARC was a reaction to Colombia's consecutive failures "to address the needs of the urban and rural poor in the late-1950s and early-1960s" (Offstein, 2003).



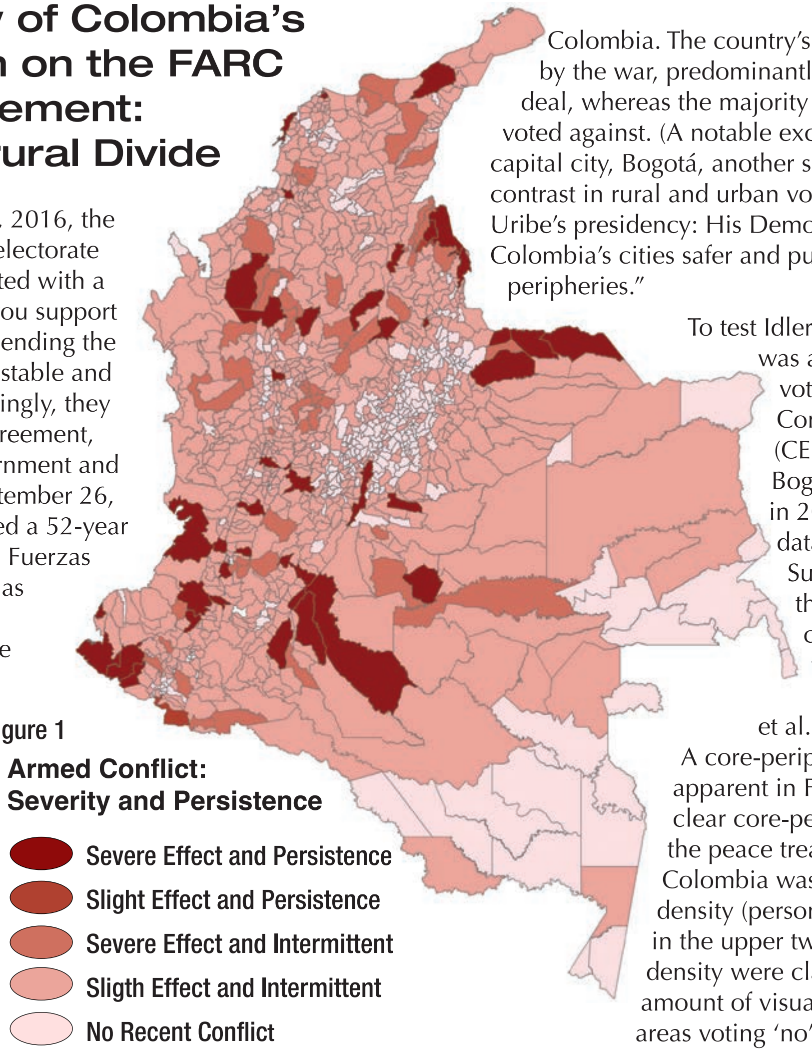



Figure 1

**Armed Conflict: Severity and Persistence**

Colombian President Juan Manuel Santos announced to the public on September 4, 2012 that his government would initiate formal peace talks with the FARC. The national government and the FARC issued their first joint communique on October 18, 2012 in Oslo, Norway (Informe del Centro Nacional de Memoria Histórica, 2014).

The peace process was not without its detractors. Ex-President Álvaro Uribe rejected the peace process favoring, like many others, retribution to end the guerrilla violence as opposed to restitution. Uribe's opposition to the process gained support and polls showed that a majority of Colombians were opposed to both FARC's conversion to a political party and "opposed to the accord's model of restorative justice" (Piri, 2016). Perla and Bazak (2016) describe the contentious battle stating, "throughout the entire process both President Santos and ex-president Uribe led fierce campaigns for and against the agreement respectively." The Colombian people rejected the peace agreement with 50.24 percent voting 'no.' Some argue that the 'no' vote was not representative of Colombia since "less than the 40 percent of Colombians voted in the plebiscite" (Idler, 2016). Idler (2016) points out:

"The vote shows a solid rural-urban divide in Colombia. The country's peripheries, most torn by the war, predominantly voted in favor of the deal, whereas the majority in the interior of the country voted against. (A notable exception was Colombia's capital city, Bogotá, another supporter of the deal). The contrast in rural and urban voting may reflect a legacy of Uribe's presidency: His Democratic Security Policy made Colombia's cities safer and pushed the conflict toward the peripheries."

To test Idler's (2016) assertion that there was an urban rural divide in the vote, data were acquired from the Conflict Analysis Resource Center (CERAC) (www.cerac.org.co), a Bogotá based think tank established in 2005 to gather and disseminate data on Colombia's armed conflict. Summarizing information from their database, CERAC has categorized each municipio by the severity and persistence of the armed conflict (see Restrepo et al., 2003 for their methodology). A core-periphery divide is somewhat apparent in Figure 1. Figure 2 shows a clear core-periphery divide in support of the peace treaty. The urban-rural divide in Colombia was delineated using population density (persons per km$^2$) (Fig. 3). Municipios in the upper two quartiles of population density were classified as urban. There is a fair amount of visual correspondence between the areas voting 'no' for the peace treaty and areas classified as urban. While the cartographic evidence suggests that Colombians least impacted by the conflict voted against the peace treaty, map reading can be subjective. Figure 4 presents a more objective analysis using optimized hot spot analysis of the percentage of 'yes' votes in each municipio. Hot spot analysis assesses whether high or low values are clustered in space and can help identify or highlight patterns on a map. The hot spot analysis results strengthen the cartographic evidence that rural Colombians, who were far more often victims of FARC violence and extortion, supported the peace treaty.

While the majority of municipios that voted in favor of the peace treaty were rural, a statistical analysis using a 2x2 contingency table (Table 1) does not support Idler's assertion of the urban-rural divide in the vote ($\chi^2 = 1.21$, df = 1 , p = 0.27). Additional

| | Urban | Rural |
|---|---|---|
| Yes | 272 | 309 |
| No | 273 | 270 |

***Source:*** www.cerac.org.co

**Table 1:** Municipio voting patterns by urban-rural status.

Figure 2

**Peace Agreement Results**

No (to the peace agreement)

Yes (to the peace agreement)

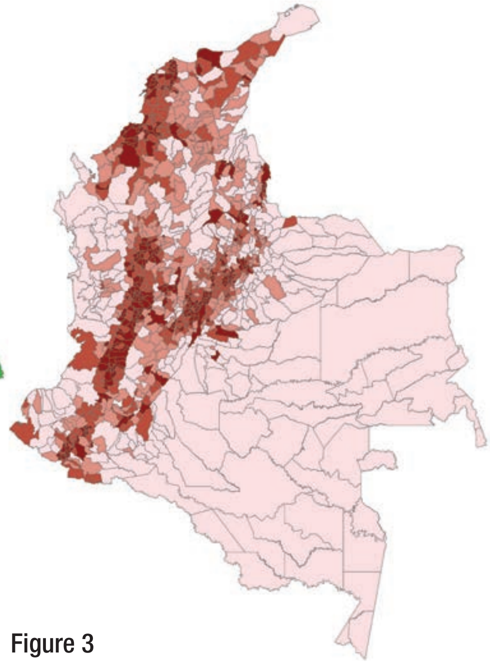


Figure 3

**Peace Agreement Population Density**

0.08–20.68

20.69–43.61

43.62–87.11

87.12–12,052.92

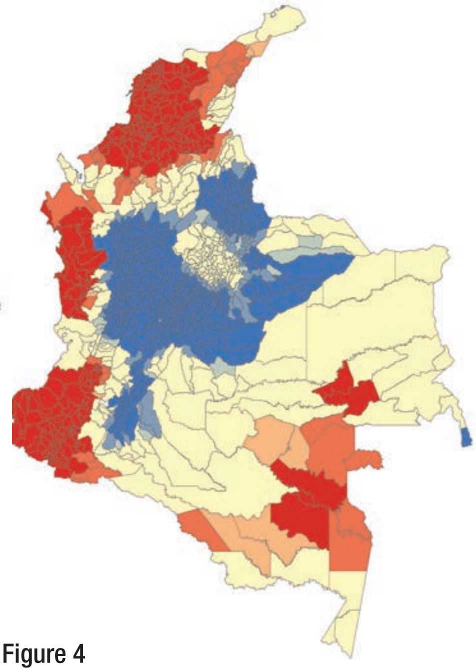




Figure 4

**Optimized Hot Spot Analysis**
**Percent "Yes" vote for the referendum**

Cold Spot - 99% Confidence

Cold Spot - 95% Confidence

Cold Spot - 90% Confidence

Not Significant

Hot Spot - 90% Confidence

Hot Spot - 95% Confidence

Hot Spot - 99% Confidence

research is required to refine the simplistic delineations of urban-rural and to explore whether the differences in voting patterns are truly rural-urban or simply core-periphery.


**REFERENCES**

BBC News. 2016. Who are the FARC? Retrieved from http://www.bbc.com/news/world-latin-america-36605769.

Idler, A. 2016. Colombia just voted no on its plebiscite for peace. Here's why and what it means. *The Washington Post.* Retrieved from: https://www.washingtonpost.com/news/monkey-cage/wp/2016/10/03/colombia-just-voted-no-on-its-referendum-for-peace-heres-why-and-what-it-means/.

Informe del Centro Nacional de Memoria Histórica. 2014. *Guerrilla y Población Civil: Trayectoria de las FARC, 1949-2013.* Centro Nacional de Memoria Histórica: Bogotá, Colombia. pp. 393.

Offstein, N. 2003. An historical review and analysis of Colombian guerrilla movements: FARC, ELN, and EPL. *Desarrollo y Sociedad.* 52: 99-142.

Perla, H. and J. Bazak. 2016. The Colombian-FARC Agreement: a fragile step toward a sustainable peace. Council on Hemispheric Affairs. Retrieved from: http://www.coha.org/the-colombia-farc-agreement-a-fragile-step-toward-a-sustainable-peace/#_edn15.

Piri, N. 2016. Colombian vote shocks predictions. Council on Hemispheric Affairs. Retrieved from: http://www.coha.org/colombian-vote-shocks-predictions/.



**AUTHORS**

*José R. Díaz-Garayúa, Ph.D.*
*Assistant Professor, Geography and Director, GIS*
*Anthropology, Geography, & Ethnic Studies Department*
*California State University, Stanislaus*
*jdiazgarayua@csustan.edu*

*Kevin A. Butler, PhD*
*Engineer Product – Spatial Statistics*
*ESRI*
*kbutler@esri.com*

*Natalia Garzón-Cubillos, MA, MBA*
*Geomatic and cadastral engineer*
*Independent consultant in Colombia and Panama*

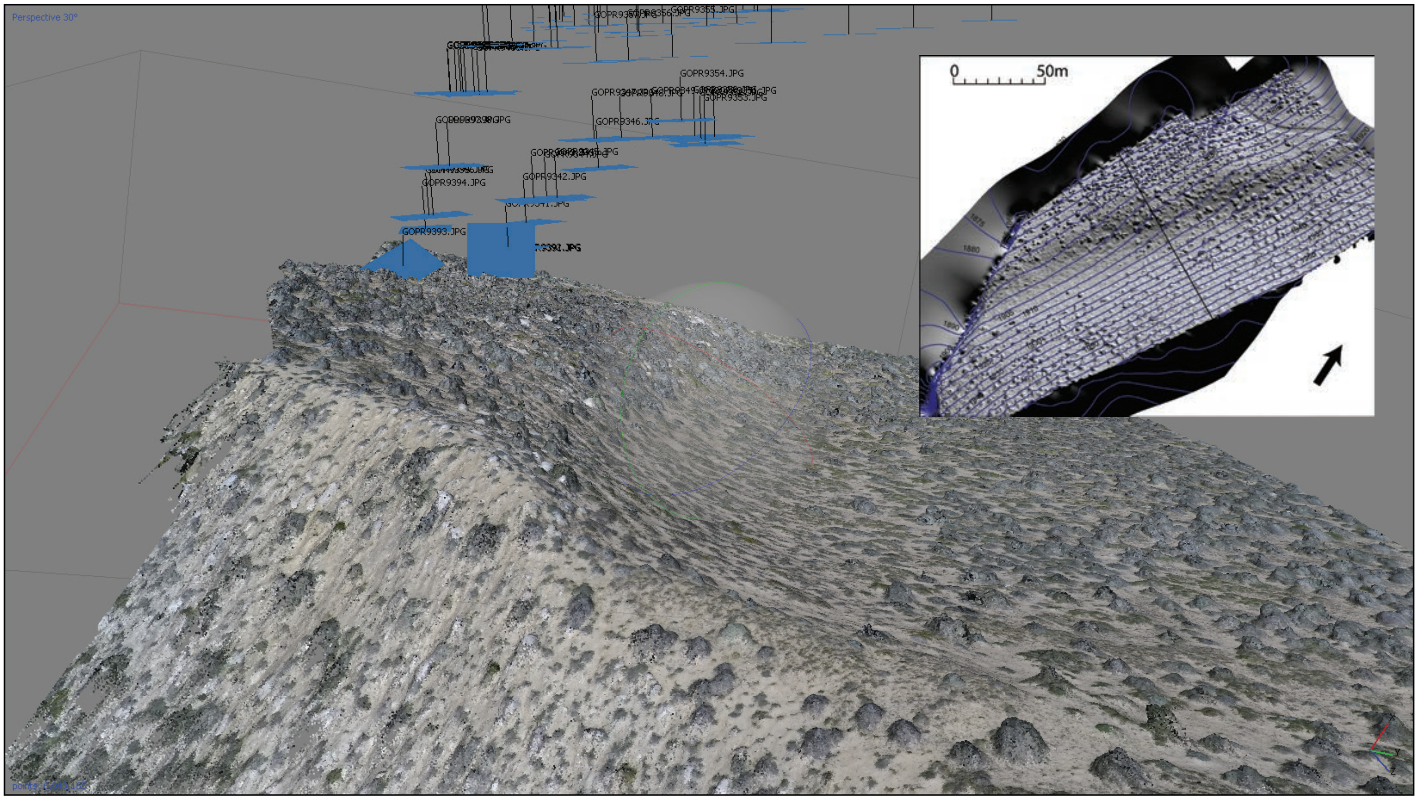





**Figure 2:** 3D high-resolution image of the side view of fault scarp from the Sierra Nevada Mountains. The slope in the images show the offset of the alluvial fan students measured to determine the rate of fault movements along the Sierra Nevada frontal fault system. Aerial photographic image of the scarp processed in AgiSoft from photos taken by students on a field trip to the Sierra Nevada Mountains. **Inset:** Digital topography data showing offset alluvial fan displaying a fault scarp. The black line is projected across the fault and is used in the class to measure the amount of offset of the alluvial fan. Purple lines show elevation contours.

along active faults of the Sierra Nevada Mountains. Students then combined this digital topography data in ArcGIS, with published scientific work of the location (Le et al., 2007) and field observations to quantify uplift rates in the region (Figure 2). These rates of fault movement were then used to assess seismic hazard in the region.

The use of high-resolution digital topography data, i.e. LiDAR, is essential to the study of active tectonics and assessing earthquake hazard in a region. Until recently, the ability to acquire such datasets has been expensive, cumbersome and time consuming. In Spring 2016, the Geology Department at SJSU acquired a DJI drone, a gaming computer, and 2 handheld GPS units (funded through SJSU e-Campus Technology grants) to efficiently and rapidly collect low cost yet high quality, high-resolution digital topography data. In the classroom, students compiled high-resolution digital topography data collected in the field via DJI drone and a GoPro camera with GPS capabilities to construct 1:2000 scale geomorphic maps from photogrammetry (Figure 2). The photos were then stitched together in Agisoft Photoscan to create ~1 m digital elevation data of the landscape, where shaded relief maps of the landscape, fault offsetting landforms and alluvial deposits were revealed (Figures 2). High-resolution digital topography data revealed geomorphic features that were offset and easily identifiable to allow for detailed mapping and eventual seismic hazard assessment. Features such as beheaded streams and offset fan deposits clearly demonstrated the active nature of the faults bounding the Sierra Nevada Mountains.

#### REFERENCES

Bonwell, C.C., and J. A. Eison. 1991. *Active learning: Creating excitement in the classroom.* ASHE-ERIC Higher Education Report No. 1. Washington, DC: George Washington University.

Le, K., Lee, J., Owen, L.A., Finkel, R. 2007. Late Quaternary slip rates along the Sierra Nevada frontal fault zone, California: Slip partitioning across the western margin of the Eastern California Shear Zone-Basin and Range Province. *Geological Society of America Bulletin.* 119(1-2): 240-256. doi 10.1130/B25960.1.

Prince, M. 2004. Does active learning work? A review of the research. *Journal of Engineering Education.* 93(3): 223-231.

#### AUTHORS

*Jennifer Redd, PhD*
*Director, eCampus*
*San Jose State University*
*jennifer.redd@sjsu.edu*

*Kimberly Blisniuk, PhD*
*Assistant Professor, Geology*
*San Jose State University*
*kimberly.blisniuk@sjsu.edu*

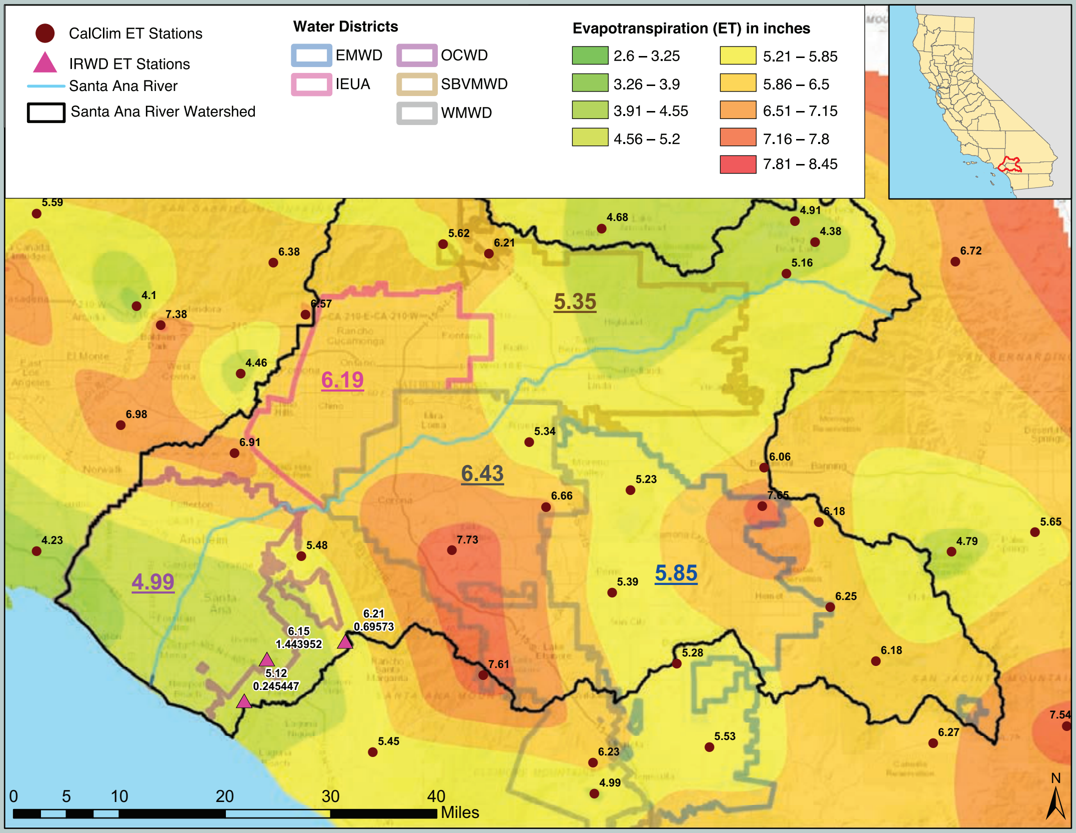



**Figure 1:** The results from the evapotranspiration surface model and the Irvine Ranch Water Agency's test locations.

tabular information provided by CalClim along with the existing CIMIS data, and converted into a shapefile. The georeferenced evapotranspiration data for the set of stations were then run through an interpolation tool called "Natural Neighbor" to create an estimated continuous evapotranspiration surface. The results display nine equal intervals with the lowest (in green) showing the lowest scoring zones of 2.6-3.25 inches and the highest evapotranspiration zones (in red) showing 7.81-8.45 inches lost due to evapotranspiration.

The numbers on the map show evapotranspiration averages that were calculated within each member agency (indicated by polygons) based on the ET total monthly average surface map generated in the previous step. The approach was to use the "Extract by Mask" tool, to clip out the ET data from the watershed for each agency's service area. Subsequently we used map algebra to create an average loss across their geographical service area for each individual member agency.

The model was tested along Irvine Ranch Water District's (IRWD's) three evapotranspiration stations located in the Santa Ana Mountain foothills, their headquarters in Irvine, and the San Joaquin hills to represent the coastal areas. The points were plotted to correspond with 3 stations and the data taken and totaled for evapotranspiration that had taken place during the study year (August 2013–September 2014). Using "Extract Values to Points" tool in ArcMap, the station points were assigned a value based on the results generated from the total ET values for the entire watershed exercise. The foothill ET station scored a difference of 0.6957 inches, the central station scored 1.4439 inches, and the coastal station scored 0.2454 inches (Figure 1).

The goal of the project was to create a better way of calculating evapotranspiration and update the data used. This project helped demonstrate the differences in water loss across the watershed, estimate the evapotranspiration rates for areas not near any stations, provide better assumptions for forecasting water use in the future, and provide a spatial tool that can potentially save time and money. Some of the drawbacks to this approach were the need for more stations to build a better model. As part of a small trial of conformation, the IRWD ET data were added and made little change to the overall watershed. The results confirmed the change in the climate zones between the immediate coast and inland Orange County. While gathering data, additional ET stations were located in San Bernardino and Fullerton, however, there was no archive available online and the request for data is still pending. Future steps for this research will be to take weather station data from the National Weather Service and calculate the Penman equation.



**REFERENCE**

California Climate Data Archive. (2014, March 04). Retrieved October 22, 2014, from http://www.calclim.dri.edu/pages/contact.html

Irvine Ranch Water District Right Scape. (n.d.). Retrieved October 22, 2014, from http://rightscapenow.com/landscape-resources/et-weather-center

Santa Ana Watershed Project Authority. (n.d.). Maps and Data. Retrieved October 22, 2014, from http://www.sawpa.org

**AUTHORS**

*Samuel Hiebert*
*GIS Analyst*
*City of Victorville, CA*
*shiebert@victorvilleca.gov*

*Michael Reibel*
*Professor, Geography*
*Cal Poly Pomona*
*Pomona, CA*
*mreibel@cpp.edu*

CSU Geospatial Review
CSU GIS Specialty Center
San Francisco State University
1600 Holloway Avenue
San Francisco, CA 94132

*Pomona*

## Santa Ana Watershed Evapotranspiration Surface Model

Water in California has become a hot topic issue in the state. In the Inland Empire region of Southern California, groundwater is becoming a closely monitored source to help subsidize the growing population of the region. In recent years, a call for smart water use has become a battle cry to combat the ever increasing years of drought in the state. Outdoor water use is an easy way to cut back on unnecessary use of otherwise clean water. State government and water agencies are taking notice of the unique characteristics of Southern California's climates and evapotranspiration which are now factors in calculating both water allotment and pay rate. Evapotranspiration (ET) is the water transferred from all land surfaces to the atmosphere. Using the Penman equation, a total loss can be measured in inches from a particular site. The California Irrigation Management Information System (CIMIS) records the amount of water loss on its stations across the state. Much of the data collected is limited to agricultural areas such as California's Central Valley and does not paint a clear picture of urban evapotranspiration. Other state and federal agencies such as U.S. Forest Service (USFS), State and Private Forestry (S&PF), Bureau of Land Management (BLM), and Desert Research Institute (DRI) use weather stations to measure evapotranspiration and all the data are archived in the California Climate Archive (CalClim).

We created a model to demonstrate the use of GIS in relation to these stations and the ability to calculate the evapotranspiration rate in and around the watershed (Figure 1). This project was part of an independent study by Sam Hiebert under the supervision of Dr. Mike Reibel, and in conjunction with Sam's internship at the Santa Ana Watershed Project Authority. The point data used were obtained from CIMIS and the CalClim profile page displaying the coordinates for 97 continuous daily reporting stations managed and operated by USFS, S&PF, BLM, DRI, CalClim research stations, and CIMIS. Because the data are based on a monthly total amount and averaged across the study year, other stations recording daily evapotranspiration were exempt since they did not provide consistent data. Data for a 1-year period (August 2013-September 2014) included sites throughout the watershed and in the surrounding areas and were used to improve the interpolation of the estimated surface areas without stations. Our findings demonstrate how GIS can be used to calculate ET rates and how the effects of topography and distance to the coast can have an effect on evapotranspiration lost over a given year.

The points representing the stations' location were added based on the coordinate locations obtained from both CalClim and CIMIS. The points were then geocoded, joined to the

*continued on page 11*