California Institute for Water Resources
Annual Technical Report
FY 2016

Introduction

The California Institute for Water Resources (CIWR) is a special program within the University of California's (UC) Division of Agriculture and Natural Resources (ANR). The Institute is enabled by the federal Water Resources Research Act (WRRA), with the mission of supporting research and extension activities that contribute to the efficient management of California's water resources, in water quality, quantity, and reliability.

Headquartered at ANR's offices within the UC Office of the President, CIWR is well positioned to coordinate research, education, and extension activities across the 10 campuses of the UC system, as well as academic institutions across the state. Throughout California, ANR is an engine for problem solving. Serving as the bridge between local issues and the power of UC research, ANR has more than 300 campus-based specialists and county-based advisors working to bring practical, science-based answers to Californians.

CIWR brings together federal, state, and local communities to identify issues and builds support for water-related research. The CIWR mission is to provide leadership that links stakeholders with UC resources to carry out statewide water planning, research, and outreach.

Given the WRRA statutory mission of education and outreach, CIWR is best suited to linking water research to the needs of water managers and users throughout California. The CIWR serves an important linkage niche: science to public policy, science to education and outreach, researchers to State agencies and the public, ANR initiatives to each other, UC water centers to each other, and UC water centers to other academic institutions.

The Institute's Director is housed within ANR to facilitate a statewide focus. The Institute also has affiliate faculty from ANR, the different UC and California State University campuses and other universities as appropriate. The CIWR Director serves as a key spokesperson on California water issues; working with federal, state, regional, nonprofit, and campus stakeholders to improve the understanding of water issues through advocacy and outreach programs.

The Director also serves as Leader for ANR's Strategic Initiative on Water Quality, Quantity and Security. Thus, part of CIWRs mission is to assist ANR in the management of this Strategic Initiative. As part of that Initiative, CIWR helps to manage ANR's competitive grants portfolio. Through this partnership, CIWR is developing such strategic themes of importance as irrigation efficiency, ecosystem services, source water production and protection, water policy, drinking water, food safety, and water quality.

Research Program Introduction

The California Institute for Water Resources (CIWR) is involved in two competitive grants programs. We manage a Request for Proposals to allocate funds from our USGS 104b program. We also assist, through the University of California Agriculture and Natural Resources (ANR) Water Strategic Initiative, with the ANR competitive grants program.

USGS 104b: The CIWR receives funds from USGS that are used to support the operations of the Institute, our Information Transfer and our Competitive Grants Program. Information on outcomes from our 104b competitive grants program is provided elsewhere in this report.

ANR Grants Programs: ANR invests in research, education and outreach projects that meet the goals of its mission by conducting a competitive grants program aimed to support high priority issues, encourage collaboration among ANR representatives and key players from throughout the state, support short-term high-impact projects, continue to strengthen the research-extension network, yield policy relevant outcomes, and achieve significant statewide economic, environmental and social impacts in California. To address some of these challenges, ANR developed the Strategic Vision 2025 to identify and meet the statewide scientific, technological, social, and economic demands facing California. As an initial implementation strategy, ANR identified five Strategic Initiatives that are favorably positioned within the Division to achieve maximum results. To attest to the importance of California water research, one of the five grant categories is specifically dedicated to “Water Quality, Quantity, and Security.”

2016 Highlights

Advisory committee: We continue to work with our advisory committee to administer the junior investigator competitive grants program. The committee is also involved in strategic planning for the Institute.

Competitive grants program: CIWR continued its competitive grants program in 2016. Working with our advisory committee, we solicited proposals for California water related research, education, and extension projects from academics at qualified institutions statewide to be funded under the 2016 WRRA (contingent on funding). We supported several new projects on topics ranging from groundwater recharge to water conservation policy – all topics of concern in the state.

Drought: Much of our effort this year continues to be related to historic drought in California. We grew an already strong web presence, leveraging additional funds from the California Department of Water Resources and gathering academic drought information, providing information on drought related events held by the UC system, and providing media contacts and information. Our Twitter following has exploded with our drought coverage and this year we surpassed 6500 followers. Although we did receive a larger amount of precipitation this year, we expect to continue our work on water security in California.

Nitrates in groundwater: Building on our 2013-15 work, we held additional training for over 100 California Certified Crop Advisors on nitrogen and water management, leveraging support through a project with the California Department of Food and Agriculture. These trainings were very well received. Our annotated nutrient and water management curriculum is now also available on the web for access beyond the in-person training opportunities.

Additional highlights: We continue to work to communicate University based science to our stakeholders, with a renewed focus on highlighting the work of a diversity of researchers across the system.

Rosenberg International Water Policy Forum: The Forum brings water scholars from the around the world together on a biannual basis to collaborate on water related conflict.

Numerical Modeling of Local Intense Precipitation Processes

Basic Information

Title:	Numerical Modeling of Local Intense Precipitation Processes
Project Number:	2015CA368S
USGS Grant Number:	
Sponsoring Agency:	Nuclear Regulatory Commission
Start Date:	3/6/2016
End Date:	3/15/2016
Funding Source:	104S
Congressional District:	44
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Water Use, Water Quantity
Descriptors:	None
Principal Investigators:	Levent Kavvas

Publications

1. Kavvas, M. L., Ishida, K., Mure-Ravaud, M. January 23-25, 2017. Numerical Simulation of Local Intense Precipitation. Presentation given at the 2nd Annual U.S.NRC Probabilistic Flood Hazard Assessment Workshop at U.S. NRC Headquarters Rockville, Maryland.
2. Mure-Ravaud, M., Ishida, K., Kavvas, M. L., Yegorova, E., Kanney, J. May 23, 2017. Reconstruction of the precipitation fields of intense historical Tropical Cyclones with the Weather Research and Forecasting (WRF) model in the simulation mode. Poster presentation given at the World Environmental & Water Resources Congress at Sacramento, California, May 21-25 2007
3. Mure-Ravaud, M., Ishida, K., Kavvas, M. L., Yegorova, E., Kanney, J. May 25, 2017. Reconstruction of the precipitation field in a Training Line/Adjoining Stratiform Mesoscale Convective System in the simulation mode with the Weather Research and Forecasting (WRF) model. Oral presentation given at the World Environmental & Water Resources Congress at Sacramento, California, May 21-25 2007

RESEARCH PROGRAM:

The objective of this project is to assess the suitability of a regional numerical weather model in simulating local intense precipitation processes, and then to investigate the physical mechanisms of storm systems that lead to extreme precipitation. Tropical Cyclones (TCs) and Mesoscale Convective Systems (MCSs) are such storm systems that are recognized for their ability to generate intense precipitation which can create disastrous floods.

In this project, we have assessed the suitability of the Weather Research and Forecasting (WRF) model to simulate local intense precipitation processes within intense historical TCs and MCSs which have affected the United States. The NCEP Stage-IV precipitation dataset, which is a mosaic of regional multi-sensor analysis generated by the National Weather Service River Forecast Centers (RFCs) since 2002, was used to select the storm systems that we simulated in this project. The selected storm systems span the period from 2002 to the present, and correspond to the most severe storms in terms of the generation of an intense precipitation field containing pockets of extreme rainfall. The initial and boundary conditions for our simulations were obtained from the Climate Forecast System Reanalysis (CFSR) dataset.

For the simulations of the MCSs, the model's simulation nested domains were set up over a region in the Midwest so that the innermost domain covered the severe precipitation areas caused by these storm systems. However, several sets of nested domains were prepared for the simulations of the TCs because of the diversity in the paths of these systems. More precisely, while the outer domain was the same for all cases and was chosen so as to cover the paths of all the identified severe TCs, different inner domains were set up so as to include the severe precipitation areas caused by each individual TC. With these sets of nested domains, we configured the WRF model to obtain the best results for the simulation of each of the selected severe MCSs and TCs with respect to the simulated and observed precipitation fields.

We compared the simulation results with observations from the Stage-IV precipitation dataset. On the one hand, the simulation results were evaluated by means of several goodness-of-fit statistics: the relative error for the simulation inner-domain total precipitation, and the percentage of overlapping between the simulated and observed fields for several precipitation thresholds. Meanwhile, the simulated and observed precipitation fields were plotted to visually appreciate the similarities and differences in the fields' texture and structure. From this comparison, we found that under an appropriate choice of the model's options and initial/boundary conditions, the WRF model managed to reconstruct in the simulation mode (meaning without any nudging or data assimilation) the precipitation fields of these severe historical TCs and MCSs.

Currently, we are investigating the physical mechanisms of these severe weather systems that lead to extreme precipitation over the United States. Once we identify these physical mechanisms, we will utilize them to simulate extreme precipitation over some selected locations over the Continental United States.

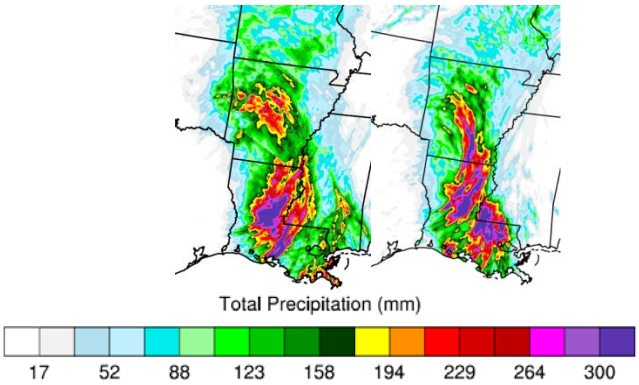

Figure 1 – Observed (left) and simulated (right) precipitation fields in Hurricane Gustav (2008). Total inner-domain accumulated precipitation from 08/31 00h to 09/05 12h.

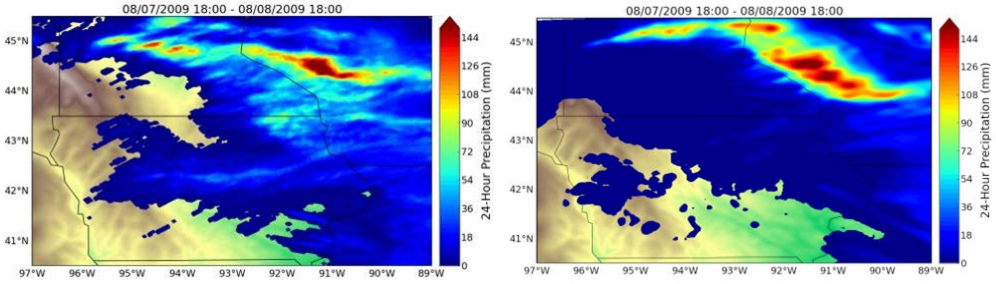

Figure 2 – Left: observed 24-hour accumulated precipitation fields (Stage-IV) during the 2009 August 08 MCS event. Right: simulated 24-hour accumulated precipitation fields during the 2009 August 08 MCS event, using the best parameterization scheme.

INFORMATION TRANSFER/OUTREACH PROGRAM:

The project team participated in the U.S. NRC 2nd Annual Probabilistic Flood Hazard Assessment Workshop at Rockville, Maryland in order to present the project's results to date.

Using Soil Exopolysaccharides (EPS) to make California grapes more drought-adapted

Basic Information

Title:	Using Soil Exopolysaccharides (EPS) to make California grapes more drought-adapted
Project Number:	2016CA358B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	44
Research Category:	Ground-water Flow and Transport
Focus Category:	Agriculture, Nutrients, Water Use
Descriptors:	None
Principal Investigators:	Joseph Blankinship

Publications

1. Blankinship, Joseph, Steven Fonte, Johan Six, and Joshua Schimel, 2016, Plant versus microbial controls on soil aggregate stability in a seasonally dry ecosystem, Geoderma, 272, 39-50.
2. Marchus, Kenneth, Joseph Blankinship, and Joshua Schimel, In review, Environmental controls on extracellular polysaccharide accumulation in a California grassland soil, Soil Biology and Biochemistry.
3. Blankinship, Joseph, Henry Morse, Kenneth Marchus, and Joshua Schimel, In prep, Using extracellular polysaccharides to conserve soil water and nutrients. Applied Soil Ecology.
4. Blankinship, Joseph, 25 March 2016, The brown belowground, Public lecture at University of California's Sedgwick Reserve with over 80 docents and concerned citizens in attendance.
5. Morse, Henry, Joseph Blankinship, and Joshua Schimel, 17 May 2016, Agricultural applications of microbial extracellular polysaccharides, Poster presentation at University of California Santa Barbara's 2016 Undergraduate Research Colloquium.
6. Morse, Henry, 19 April 2016 and 17 May 2016, Agricultural applications of microbial extracellular polysaccharides, Oral presentations at University of California Santa Barbara's Undergraduate Research SLAM competition which is designed to foster effective scientific communication; Henry was one of the finalists.
7. Blankinship, Joseph, Henry Morse, Carlos Rodriguez, Kenneth Marchus, and Joshua Schimel, 6 November 2016, Oral presentation, Using extracellular polymeric substances (EPS) from bacteria to make soils more drought-adapted, Agronomy Society of America/Crop Science Society of America/Soil Science Society of America Joint 2016 Annual Meeting, Phoenix, AZ.
8. Blankinship, Joseph, Kenneth Marchus, and Joshua Schimel, 8 June 2017, Oral presentation, Using extracellular polysaccharides to conserve soil water and nutrients while sustaining plant growth, Ecology of Soil Health Summit, Fort Collins, CO.
9. Blankinship, Joseph, Henry Morse, Carlos Rodriguez, Kenneth Marchus, and Joshua Schimel, 6 November 2016, Oral presentation, Using extracellular polymeric substances (EPS) from bacteria to make soils more drought-adapted, Agronomy Society of America/Crop Science Society of America/Soil Science Society of America Joint 2016 Annual Meeting, Phoenix, AZ.

10. Blankinship, Joseph, Kenneth Marchus, and Joshua Schimel, 8 June 2017, Oral presentation, Using extracellular polysaccharides to conserve soil water and nutrients while sustaining plant growth, Ecology of Soil Health Summit, Fort Collins, CO.

RESEARCH PROGRAM:

The scientific community is calling out for “climate-smart” soils that both mitigate *and adapt to* climate change, but how do we actually accomplish this? One soil-based strategy for drought adaptation is to enhance soil organic matter (SOM), because SOM is an effective sponge for capturing and retaining water from irrigation or natural precipitation. But which kind of SOM is most effective for making soils “water smart?”

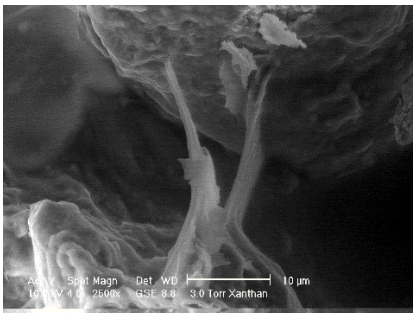

Fig 1. Xanthan gum in soil; image captured using environmental scanning electron microscope

Fig. 2. Collecting soil at Sea Smoke Vineyard near Lompoc, CA

Fig. 3. Growing pinot noir grapevines in soils amended with xanthan gum

When soils dry out, bacteria are known to secrete extracellular polymeric substances (EPS) into the soil environment, which are potent forms of SOM. EPS are remarkable at holding onto water molecules and are thought to be an evolutionary adaptation of bacteria to water-limited conditions. EPS also act as pipes to increase the diffusion and physical accessibility of soluble resources. While it remains difficult and unclear how to extract bacterial EPS from soil, it *is* possible to add EPS to soil because xanthan gum is commercially available, organically certified EPS produced by bacteria.

The overarching goal of this project was to explore the potential benefits of bacterial EPS for reducing irrigation demand while sustaining soil nutrient supply and plant production. My objective was to add an EPS analog to quantify its function in a plant-soil system. Do EPS contribute to water savings, crop production, and nutrient retention?

Soils from a pinot noir grape vineyard on the central coast of California were transferred to 5-gallon pots and transported to a greenhouse at University of California at Santa Barbara. After growing winter cover crops and simulating tillage, three xanthan gum treatments were set up: 1% (by mass), 0.5%, and no xanthan added. Pots of soil with and without grapevines were maintained for a six-month growing season. Pots were irrigated whenever soil at a depth of 10 cm dried below 15% volumetric water content. Irrigation amount, soil moisture at 10 cm and 30 cm depths, plant growth (dry biomass, stem length, leaf count), and fluxes of plant-available soil nitrogen (nitrate, NO3-) were monitored throughout the growing season using buried ion-exchange membranes.

Xanthan gum amendment reduced seasonal irrigation demand by 28-38% in bare soils. Surprisingly, it took over two months for the soil wetting front to reach a depth of 30 cm due to changes in porosity and infiltration rate. Increased moisture associated with xanthan gum gradually shifted from shallow to deep soils. With grapevines present,

xanthan amendment did not affect irrigation demand, but plant production increased by 55%, resulting in a 45% increase in crop water-use efficiency. Xanthan gum also moderated the rapid release of NO3- early in the growing season.

The beneficial effects of microbial EPS on soil water and nutrient retention, as well as plant growth, should motivate land managers to promote natural EPS production and links to soil health. For young perennial crops and severely degraded soils, xanthan gum amendment in the rooting zone could be an economically viable strategy for reducing irrigation demand and jumpstarting ecosystem recovery, particularly during drought.

Fig 4. Amending vineyard soils with xanthan gum

INFORMATION TRANSFER/OUTREACH PROGRAM:

Goals, data, and impacts of this project have been transferred through a variety of forums:

1. Docents and concerned citizens at UC Sedgwick Reserve and Santa Clara River Restoration; the lecture and field trip included discussion of the importance of soil organic matter and microbial EPS for agricultural sustainability and ecosystem drought resilience;
2. Santa Barbara County government and resource conservation leaders at a soil carbon meeting in downtown Santa Barbara to improve soil health in California rangelands;
3. Agricultural industry outreach: Agri-Turf Supplies (Santa Barbara, CA); Frey Farming Vineyard Management (Buellton, CA); Prolific Earth Sciences (Dr. Judith Fitzpatrick, Englewood, NJ); Ecological Landscape Management (James Sittilo, Hauppauge, NY);
4. Farmer outreach: Sea Smoke Vineyard (Victor Gallegos, Lompoc, CA), Manzanita Berry Farm (Dave Peck, Santa Maria, CA), and Roots Organic Farm (Jacob Grant, Santa Ynez, CA);
5. University of California Cooperative Extension in San Luis Obispo and Ventura;
6. University of California Santa Barbara undergraduate research colloquium;
7. International conference presentations at the ASA/CSSA/SSSA Tri-Societies Annual Meeting and the Ecology of Soil Health Summit.

Explaining Current and Future Trends in Adoption by California Municipalities and Counties of Policies Limiting or Banning High-Volume Hydraulic Fracturing

Basic Information

Title:	Explaining Current and Future Trends in Adoption by California Municipalities and Counties of Policies Limiting or Banning High-Volume Hydraulic Fracturing
Project Number:	2016CA359B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	44
Research Category:	Climate and Hydrologic Processes
Focus Category:	Groundwater, Hydrology, Law, Institutions, and Policy
Descriptors:	None
Principal Investigators:	Gwen Arnold

Publications

There are no publications.

RESEARCH PROGRAM:

We are investigating the factors that affect whether a sub-state jurisdiction in California adopts a policy intended to restrict or prevent HVHF locally. To do this, we surveyed jurisdictions regarding the actions they have taken with respect to HVHF, their evaluation of the opportunities and challenges posed by HVHF, and the attitudes toward and concerns about HVHF held by their citizens. We are collecting public meeting minutes from all California municipalities so that we can search these records for policies, resolutions, or other policy actions taken by municipalities to tackle HVHF. Finally, we are interviewing stakeholders and decision-makers involved in campaigns to pass county-level anti-HVHF measures.

Public record collection is an important part of our research program because our experience doing a similar investigation in New York over the last few years showed us that if we contact municipalities and ask them (via the state's public records statute) to provide us with documentation of laws, resolutions, and regulations pursued vis-a-vis HVHF, they may overlook important policy actions and documents. (They do not necessarily index their records by subject and thus the records we can obtain is often dependent on the clerk's memory of policy passage.) By collecting the minutes of their public meetings, we can comprehensively search them for references to HVHF ourselves, applying the same search terms and protocols. In this way, we can ensure that we have comparable policy data for all jurisdictions.

We have not yet comprehensively analyzed the survey data. Our initial assays of those data suggested that few municipalities passed anti-HVHF measures, in part because of the issue's relatively low salience in most places in California and in part because counties play a large role in local land use governance. Our increasing awareness of the importance of county action on HVHF prompted us to investigate county-level efforts via secondary source data collection and interviews. We have interviewed 15 stakeholders and decision-makers involved in county-level anti-HVHF efforts, and have additional interviews slated. Completed interviews are being transcribed. We are still transferring survey data from hard copy surveys to an electronic database, but we deemphasized this task to focus on the interviews.

Collecting public records is an involved task that we continue to pursue. Many municipalities do not post (all) of these materials online, and they must be accessed via queries submitted pursuant to the California Public Records Act. It can take a municipal clerk 1-2 months to process a CPRA request, particularly given the fact that we are asking for hundreds of pages of documents. Many municipalities send their records in hard copy, and we must scan them as electronic documents before we can store them and ultimately analyze them.

These research tasks are labor-intensive and time-consuming, in part explaining why we do not yet have substantial preliminary findings. Our reorientation this during the reporting period, to explore county-level anti-HVHF campaigns, also helps explain why we do not have completed analyses/publications. We are, however, making good

progress toward the goal of obtaining (via the survey) insights into how citizens and officials in California view and address HVHF, and (via the public records) documenting and analyzing policy actions that localities have pursued with respect to HVHF, 2010-2015.

INFORMATION TRANSFER/OUTREACH PROGRAM:

Because we have not finished data collection and analysis, we have not pursued substantial information transfer and outreach activities. The PI, Dr. Arnold, gave multiple presentations in which the ongoing California research was mentioned; the main focus of the presentations was providing an overview of HVHF and/or describing the findings from related, prior research on municipal HVHF policymaking in New York. (The New York project paved the way for the California project.) These presentations include:

- A presentation at the American Political Science Association annual conference in San Francisco in September 2016
- A presentation at the American Association for Public Policy and Management in October 2016
- A presentation to the Midwest Political Science Association annual conference in Chicago in March 2017

Characterizing the Impact of Salton Sea Water Management and Restoration Practices on Regional Air Quality

Basic Information

Title:	Characterizing the Impact of Salton Sea Water Management and Restoration Practices on Regional Air Quality
Project Number:	2016CA360B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	44
Research Category:	Climate and Hydrologic Processes
Focus Category:	Water Quality, Water Use, Management and Planning
Descriptors:	None
Principal Investigators:	Roya Bahreini

Publications

1. The Effect of a Receding Saline Lake (The Salton Sea) on Airborne Particulate Matter Composition, Frie, A.L., J.H. Dingle, S.C. Ying, and R. Bahreini, Submitted to Environ Sci. Technol. (April 2017)
2. Metal Composition and Source Identification of Particulate Matter around a Shrinking, Saline Lake (Salton Sea) via Pb Isotope and Metal Ratio Analysis, Frie, A.L., J.H. Dingle, S.C. Ying, and R. Bahreini, American Association for Aerosol Research Annual Meeting, Portland, OR, Oct. 2016.
3. California Is Running Out of Time to Save the Salton Sea, by P. Nagappan, Aug. 31, 2016 https://www.newsdeeply.com/water/articles/2016/08/31/california-is-running-out-of-time-to-save-the-salton-se

RESEARCH PROGRAM:

During March 1, 2016-Feb. 28, 2017, wet-lab analysis of aerosol and soil samples and interpretation of data were completed to determine sources of aerosols in the region using Positive Matrix Factorization (PMF). As shown in **Figure 1**, seven playa and ten desert samples were analyzed for elemental composition with inductively coupled plasma, mass spectrometry (ICP-MS). Twenty-five playa and 88 desert samples, collected from a wider area around the Salton Sea, were also analyzed via energy dispersive X-ray fluorescence spectroscopy (ED-XRF) to confirm representativeness of the smaller sample set analyzed by ICP-MS. ED-XRF and ICP-MS elemental analysis revealed consistent and unique characteristics of playa and desert soil. For both techniques, playa soils were observed to have significantly ($p \leq 0.05$) larger elemental abundances of Na, Ca, and Se and desert soils were observed to have significantly larger abundances of Ti and Mn. The larger ED-XRF dataset also revealed significantly greater abundances of Al, Fe, K, V, and Cr within desert soils. Notably, arsenic was not significantly different between playa and desert soils using either techniques, and Cd was observed at near or below detection limits of both techniques. Given these trends, increased emissions of PM from playas are expected to increase abundances of Na, Ca, and Se in airborne dust particles relative to typical desert soil emissions.

Mass concentrations of major elements (Al, Fe, Na, and Ca) were found to be within the range of previously observed values in rural areas of the American southwest. PM_{10} Na concentrations averaged at 482 ng m^{-3}. Although trace elements do not significantly increase the mass of PM, their concentrations are of interest due to their potential to increase toxicity. Cd, Se, Cr, As, Mn, and Ni can increase the toxicity of PM at high concentrations. Median mass concentrations of each of these metals were below California EPA reference exposure levels (RELs) for chronic toxicity, by factors of 77, 14e3, 18, 250, 7, and 2, respectively. Nickel was the only element to breach its REL during sampling, during 3 of the 25 sampling periods. This finding indicates that these metals likely do not increase the likelihood of PM_{10} toxicity at conditions encountered during this campaign. Mass concentration differences between seasons were not significant for most elements.

Only Na and Se displayed significant differences ($p \leq 0.05$) between summer (at Salton City and Bombay Beach) and winter (at Salton City) sampling. Average Na concentrations were 850 ± 670 ng m^{-3} and 370 ± 159 ng m^{-3} during the summer and winter, respectively. Average Se concentrations were 2.1 ± 2.7 ng m^{-3} in summer and 0.3 ± 0 .4 ng m^{-3} in winter. The lack of a seasonal difference in concentrations of the major elements other than Na suggests that separate factors control Na emissions and common desert emissions. Such variation would be expected from a playa source, as playa emissions are thought to be influenced by additional meteorological factors such as relative humidity (RH) (Buck et al., 2011), while typical dust emissions are not thought to be as sensitive to RH. Larger oscillations in RH are thought to affect the hydration state of playas, increasing irregularity in mineral structure and potentially increasing emissivity (Buck et al., 2011).

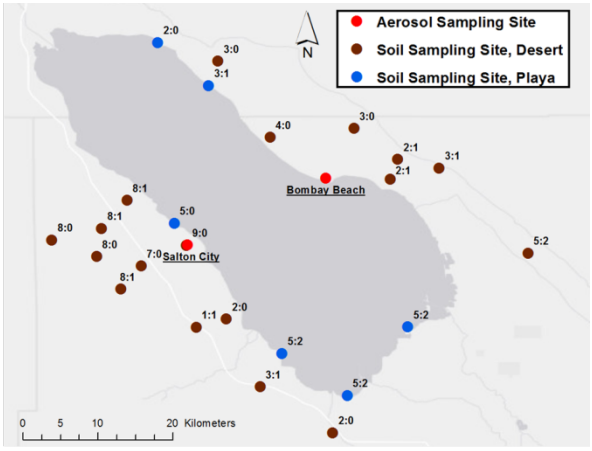

Figure 1. Map of soil and aerosol sampling sites. Labels represent the number of ED-XRF and ICP-MS analyzed soil samples from each site, presented as ED-XRF;ICP-MS.

Enrichment factors (EF) have been used widely in atmospheric and soil literature to track normalized changes in composition that are driven by anthropogenic or geologic forces. For this study, Al is used as the normalization element because it is relatively immobile in soils and has been shown to be conserved upon emission. EF in soils and aerosol samples were calculated using the following equation:

$$EF = \frac{(M_{Measured}/Al_{Measured})}{(M_{UCC}/Al_{UCC})}$$

Where $M_{measured}$ is the ICP-MS measured mass concentration of an element within a sample (ppm), $Al_{measured}$ is the ICP-MS measured mass concentration of Al within a sample (ppm), and M_{UCC} and Al_{UCC} are the analogous values for the UCC. Upper Continental Crust (UCC) composition as reported by Wedepohl (1995) was used. Samples with enrichment factors of 1 have the same elemental ratios as the UCC, values larger or smaller than 1 indicate differences from the UCC. EF distributions for playa soil, desert soil, and PM_{10} are shown in **Figure 2**. Playa soils were significantly ($p \leq 0.05$) more enriched in Na, Ca, Se than desert soils. PM_{10} was significantly more enriched than both soil types in Se, V, Cr, Ni, As, Ba and Fe. Minor and trace elements were more concentrated on smaller particles, consistent with contributions from anthropogenic emissions, while the fractions of crustal elements, those with high concentrations in the upper continental crust (Fe, Al, Ca, Ti), were concentrated on larger particles. Iron was the only major element significantly enriched in PM_{10} relative to

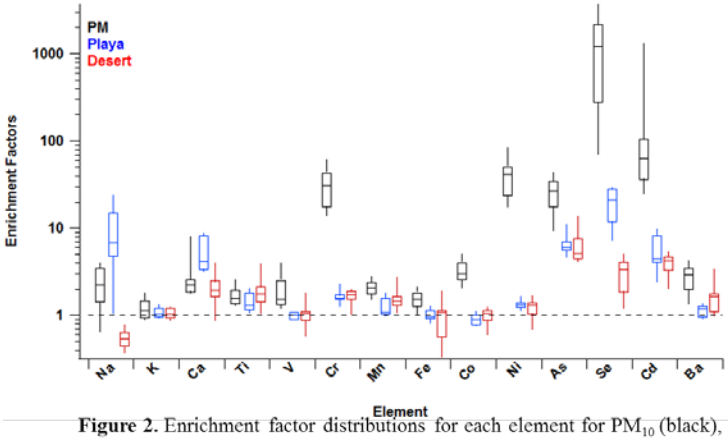

Figure 2. Enrichment factor distributions for each element for PM_{10} (black), playa soils (blue), and desert soils (red). Box and whiskers highlight 10th, 25th, 50th, 75th, and 90th percentiles.

both soil types. A combination of suspension enrichment and anthropogenic contributions are reflected in the observed enrichments in PM_{10}. PM_{10} was significantly enriched in Na relative to desert soils, but not significantly different than playa soils. This finding shows that Na enrichments in PM_{10} may arise from mixing of two sources, i.e., playa and desert soil. This enrichment suggests that playa emissions are contributing significantly to the Na within PM_{10}. Selenium displayed the largest enrichments among the trace elements and the strongest seasonal dependence: median summer and winter Se EFs were 1890 and 257, respectively. The seasonal variations in EF of Se, As, and Na, but not in elements associated with desert soils, indicates that sources of these elements are likely controlled by factors different than those controlling traditional desert emissions.

The four factors produced by PMF to describe the major sources of PM_{10} were identified as playa-like, desert-like, selenium, and Ca-rich. Notably, elements normally associated with anthropogenic emissions (such V, As, Ni, Cr, and Ba) which were observed to be enriched in PM relative to playa and desert soils were not isolated in an independent factor, likely due to the low concentrations and relatively high uncertainties associated with these elements. The playa-like factor was characterized by a prominence of Na and the presence of dust tracers such as Fe, K, and Ti. The desert-like factor was identified by the prominence of Al, Fe, K, and Ti, all of which are major elements in the earth's crust and have been observed to be prominent in regional deserts' soils. The desert-like factor is likely sourced from nearby desert and mountain surfaces. The Ca-rich factor has been found in previous source apportionment studies and often attributed to construction, secondary dust sources such as limestone or gypsum deposits, or resuspension of road dust. The Se factor was identified by the prominence of Se; 77% of all sampled Se is attributed to this factor. Given that coal combustion is the major anthropogenic source of Se and the lack of coal usage in this region, the Se factor was likely not anthropogenic in nature. One other potential Se source is Se volatilization and condensation onto PM. In this study, summer median Se EFs were seven times greater than winter, suggesting that Se volatilization from the sediments/soil and condensation onto PM is an important process at the Salton Sea. If Salton Sea playas have a greater rate of Se volatilization than Salton Sea sediments, volatilization may have become an increasingly important process after the relatively recent exposure of playas.

To quantify the burden of PM_{10} emission sources at Salton Sea, the mass contribution of major sources needs to be calculated. PM mass associated with the Desert-like factor can be estimated using the elemental concentration of Al, Ca, Fe, and Ti in dusts and the formulation from the Interagency Monitoring of Protected Visual Environments (IMPROVE) program and modified by Clements et al. (2013). Using this method, and averaging over the sampling periods, the average crustal contribution was 45.2 ± 26.4% of the total PM_{10} mass, indicating that on most days crustal sources played a major role in the observed PM_{10} mass loadings at these sites. An equation was developed using our PMF results and the playa mineral frequencies described by Buck et al. (2011). Assuming this subset of playa samples is representative of emissive playas around the Salton Sea, the ratio of Na to total mineral mass of a typical playa can be calculated. Next, using the PMF estimated Na concentration of the Playa-like factor, the total mass

contribution of playa sources can be estimated, assuming that mineralogical frequencies are conserved through the emission process. Using this estimation, playa sources contributed at an average of 8.9 ± 5.6% to PM_{10} mass over all sampling periods. The contribution of playa to PM at these sites is measurable and not negligible at current levels of playa exposure.

These contributions will likely increase with increasing playa exposures, aggravating air quality and ecological issues in the region. High dust emission events with prevailing winds crossing over the exposed playas were not sampled during this project. Since PM emissions are controlled in part by wind speed and the presence of airborne particles to aid in saltation, playa emission rates are expected to increase under higher wind conditions. Therefore, the observations here may only represent the lower bounds of current playa contributions to PM_{10}. Future PM source apportionment studies need to resolve the contributions of playas during high mass events, as playa contributions will likely be much higher and playa sources increasingly more important.

INFORMATION TRANSFER/OUTREACH PROGRAM:

- Oral presentation by PI's Ph.D. student at the Annual Meeting of the American Association for Aerosol Research
- A manuscript summarizing the results is in review at *Environ. Sci. Technol*.
- PI and her Ph.D. student have introduced the project to Riverside County high school students as part of an outreach program lead by the PI.
- Preliminary results were discussed with a freelance writer for *News Deeply, Water Deeply*

Metagenomic Analysis of Groundwater Wells for Risk Assessment and Development of Intervention Strategies to Improve Water Efficacy

Basic Information

Title:	Metagenomic Analysis of Groundwater Wells for Risk Assessment and Development of Intervention Strategies to Improve Water Efficacy
Project Number:	2016CA361B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	44
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Toxic Substances, Methods
Descriptors:	None
Principal Investigators:	Clarissa Noble

Publications

There are no publications.

RESEARCH PROGRAM:

Methodology Improvements: We continue to revise our field and lab methodologies to make sample collection more feasible in challenging field conditions. We have retooled our protocols so that the hands-on time at a well has decreased from roughly 3 hours to 8 minutes. We now have a thorough understanding of the pass-through volumes required for samples from low-turbidity supply wells. Untrained personnel who are familiar with wellhead operation can now complete the sample collection, and the risk of airborne contamination has been significantly reduced. The further refinement of these protocols allows more flexibility as the filter cartridges can be mailed between the project investigators (rather than requiring lab-trained personnel to be present and the field site for all sampling).

Sample Collection: Our capsule-filter based sample collection method is allowing streamlined sampling in a wider variety of conditions with significantly less time. Our previous method was optimized to collect a very wide size range of biological material from small viruses up to large eukaryotic cell aggregates and provided very high quality samples. However, this method was based on a kidney dialysis rig, which required extensive field equipment, sterilization of many parts, and roughly 3 hours of intensive labor per sample. Thus, the method was limited in that few samples could be collected in a given day. The new sample collection method requires very little labor, costs roughly the same amount per sample, and delivers biological material that meets our requirements. The method uses a disposable 0.2 µm flow-through filter that attaches to the well pump outflow fitting. The filter stays in place unattended until it clogs with material, which can take anywhere from 1 to 24 hours depending on the clarity of the water. In this way, many wells can be set up for sampling in a day and then the filters retrieved later. Because the filter cartridges are based on industry-standard technology, personnel unfamiliar with the project can collect samples for us (without providing us direct access to the field sites).

And because the filter cartridges are small and sealed, there is little risk of air contamination. To date, we have collected capsule filters from 36 wells, and have scrapings of biofilm materials from inside four of those wells. We were able to collect soil samples during the drilling and installation of one well to document an initial pre-well condition. These samples document a range of aquifer conditions ranging from high-capacity municipal supply wells in shallow alluvial sediments with abundant organic material (and persistent fouling problems) to monitoring wells in deep basalt aquifers. We are now content with our access to wells for sampling and are no longer pursuing new contacts at this time. Rather, we are focused on sampling this large number of wells, consisting of over 100 high-capacity municipal supply wells, which we gained access to during this reporting period.

Sample Extraction: We have refined our protocols to recover biological material from the filter cartridges, including cartridge deconstruction and membrane recovery, sample lysis, and DNA/RNA purification. Cartridge deconstruction and membrane

recovery are labor intensive, so 12 filter cartridges can be processed comfortably in a day, which means we can process a complete sequencing run in roughly a week.

Dry Lab Bioinformatics Analysis Progress: Since we are ultimately interested in discovering molecular mechanisms of well biofouling so that we can develop strategies to combat it, we are using whole metagenome sequencing. This approach gives us sequence information on all of the genomes found within a water sample. Thus we can identify specific genes that are associated with biofouling in specific well conditions. To this end, we continue to build our analysis pipeline to utilize the whole metagenome data that our lab work produces. We have further optimized our assembly pipeline and our genomic binning (assigning assembled contigs to genomes) pipeline to use largely automated curating. We have also integrated a functional annotation pipeline (ClusterFinder) that predicts operons rather than just gene functions into our workflow.

Metagenomic Assembly and Binning Pipeline: We use IDBA_UD (iterated DeBruijn graph assembler for uneven depth of sequence coverage) to assemble contigs from the raw sequencing reads. This step generates a wide range of contig sizes based mostly on the depth of coverage. We use REAPR to check that the assembled contigs are valid and break contigs where misassemblies are detected. We next assign these contigs to genomic bins using a combination of kmer frequency distribution-based methods: CONCOCT (automated), VizBin (manual), and ESOM (manual). We then use custom scripts to validate the bins. Finally, we extend the assemblies using PRICE targeted assembly, which extends and joins many of the contigs in the genomic bins. Overall, this pipeline generates much cleaner results with fewer contigs assigned incorrectly to bins. As reported in the previous reporting period, we are comfortable in distinguishing strain-level variation between genomes in individual samples.

Figure 1. Sampling trip in December 2016 to collect high-capacity municipal well samples in the City of Sacramento. Our filter setup is shown attached to each well. Sahiba Kaur-Libra (research assistant), Aaron Hernday (professor), and Thaddeus Seher (graduate student) are shown from left to right.

Functional Prediction of Operons: We are readily using the ClusterFinder module within the AntiSMASH framework to make predictions of secondary metabolite gene clusters in our genomic bins. This software predicts secondary metabolite operons using a Markov model based on clustering of similar function genes from validated reference datasets. Annotation of the above-mentioned genomes revealed rich diversity of secondary metabolite biosynthetic clusters.

INFORMATION TRANSFER/OUTREACH PROGRAM:

We are happy to report that our outreach efforts to access additional wells in California have been very successful, and we have forged new relationships with several agency contacts for municipal well sampling in Central California. Our most useful contact to date who has given us access to over 100 high-capacity municipal wells is Megan Thomas in the City of Sacramento.

Monitoring tree survival and performance in street-side stormwater management facilities

Basic Information

Title:	Monitoring tree survival and performance in street-side stormwater management facilities
Project Number:	2016CA362B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	44
Research Category:	Water Quality
Focus Category:	Wastewater, Treatment, Ecology
Descriptors:	None
Principal Investigators:	Igor Lacan

Publication

1. Lacan, Igor. 2016. Stormwater Trees: Tree growth and condition in street-side bioswales Presentation at the 2016 UC Agriculture and Natural Resources Joint Strategic Initiatives Conference, Sacramento, California.

RESEARCH PROGRAM:

Street-side bioswales planted with vegetation that often includes ornamental trees are becoming increasingly common, yet little is known about survival, growth, and health of those trees. Should trees be excluded from these facilities over concerns about their condition, as has been proposed by some municipalities, the sustainability of urban areas would be impacted. This project evaluates tree survival, growth, and condition in stormwater facilities, with street trees of the same species and comparable age used as controls, and with the city of Portland, OR (>10 years experience) serving as a long-term comparison for three cities in the San Francisco Bay Area (Berkeley, Burlingame, El Cerrito, San Carlos, and San Jose; 0-4 years experience).

In addition to measuring trees and rating their condition, I am using datalogging soil moisture sensors to monitor soil conditions – thought to be a major limitation to trees in bioswales – focusing on the potential for either excessive or insufficient soil water content.

A typical small bioswale (with trees), with stormwater flow paths outlined in blue (San Jose).

Installing soil moisture sensors in a bioswale, & connecting them to a datalogger (Portland).

INFORMATION TRANSFER/OUTREACH PROGRAM:

- Formal outreach: poster at the 2015 ANR Joint Strategic Initiative Conference
- Informal outreach: I discuss the project with municipal staff at every event where I am speaking; I have thus managed to sign up additional study partners.

Quantifying methylmercury loads from California rice fields

Basic Information

Title:	Quantifying methylmercury loads from California rice fields
Project Number:	2016CA363B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	44
Research Category:	Water Quality
Focus Category:	Agriculture, Surface Water, Water Use
Descriptors:	None
Principal Investigators:	Bruce Linquist

Publications

1. Tanner, K. Christy, Lisamarie Windham-Myers, Jacob Fleck, Kenneth Tate, Stephen A. McCord and Bruce A. Linquist, A. 2017. The contribution of rice agriculture to methylmercury in surface waters: a review of data from the Sacramento River watershed. Journal of Environmental Quality, 46:133-142, http://dx.doi.org/10.2134/jeq2016.07.0262.
2. Tanner, K. Christy, Lisamarie Windham-Myers, Mark Marvin-DiPasquale, Jacob Fleck, Kenneth Tate, and Bruce A. Linquist, 2017, Rice fields with low soil mercury export little methylmercury in drainage water and produce low methylmercury rice, (submitted).
3. Tanner, K. Christy, 2017, Methylmercury in California Rice Ecosystems, Ph.D Dissertation, Horticulture and Agronomy, College of Agriculture and Natural Resources, University of California Davis, Davis, California, 118 p.
4. Tanner, K. Christy, Lisamarie Windham-Myers, Mark Marvin-DiPasquale, Jacob Fleck, Kenneth Tate, and Bruce A. Linquist, November 9th, 2016, Alternate wetting and drying decreases methylmercury in rice ecosystems. Meeting of the American Society of Agronomy, Crops Science Society of America and Soil Science Society of America. Phoenix, AZ.
5. Tanner, K. Christy, Lisamarie Windham-Myers, Jacob Fleck, Kenneth Tate, Stephen A. McCord and Bruce A. Linquist, January 26-28th, 2016, The Contribution of Sacramento Valley Rice Systems to Methylmercury in the Sacramento River. Revisiting the 2003 Mercury Strategy for the Bay-Delta Ecosystem, Sources Workshop.
6. Tanner, K. Christy, Lisamarie Windham-Myers, Mark Marvin-DiPasquale, Jacob Fleck, Kenneth Tate, and Bruce A. Linquist, January 26-28th, 2016, Methylmercury Export from Rice: Field Scale Methylmercry Budgets for the Sacramento Valley. Revisiting the 2003 Mercury Strategy for the Bay-Delta Ecosystem, Biogeochemistry Workshop.
7. Tanner, K. Christy, June 15th, 2015, Sacramento Valley Rice Field Mercury Studies, Delta Tributaries Mercury Council.
8. Tanner, K. Christy, Lisamarie Windham-Myers, Mark Marvin-DiPasquale, Jacob Fleck, Kenneth Tate, and Bruce A. Linquist, October 29th, 2014, The Contribution of Sacramento Valley Rice Systems to Methylmercury in the Sacramento River. Eighth Biennial Bay Delta Science Conference.
9. Tanner, K. Christy, Lisamarie Windham-Myers, Jacob Fleck, and Bruce A. Linquist, Alternate wetting and drying decreases methylmercury in rice ecosystems. Rice Field Day.

RESEARCH PROGRAM:

The bioaccumulative and toxic pollutant MeHg may be produced in flooded soils such as those in rice fields. MeHg may then be accumulated in rice grain potentially affecting the health of people who consume it. Additionally, MeHg in the surface water of rice fields may be bioaccumulated by wildlife both within the fields and in downstream areas that receive rice drainage water. This can negatively impact the fitness of wildlife, and the health of humans who consume fish from affected areas. In California, MeHg in rice fields is a concern due to a history of Hg contamination in the mountains surrounding the Sacramento Valley, where 200,000 ha of tice is grown. Drainage water from Sacramento valley rice fields ultimately enters sensitive wildlife habitat the Sacramento-San Joaquin Delta. The overall objective of this research was to determine if MeHg in and discharged from CA rice systems pose a health risk to human and wildlife fish consumers, and how farmers could cost-effectively minimize that risk. Two studies were conducted to address these objectives.

Study 1: Dynamics of MeHg import and export from rice fields

While MeHg may be produced in rice fields, it may also be imported in irrigation water. Furthermore, other transformations, such as degradation mediated by microbes or light, bioaccumulation by rice plants and physical transport processes impact how much MeHg is exported in drainage water. An understanding of integrated effect of these processes is necessary to determine how rice fields impact MeHg and associated risks. The objective of this study was to determine the annual cycle of MeHg import and export from rice fields.

The annual MeHg and total Hg (THg) budget was monitored two Sacramento Valley rice fields. The fields were managed by commercial rice growers, following typical management practices for the Sacramento Valley. Monitoring involved collecting water samples from the inlet and outlet of each field during the growing and fallow seasons. The amount of water entering and leaving the field was continuously monitored to estimate loads (concentration * flow). Soil and plant samples were also collected. All samples were analyzed for MeHg and THg.

We observed low (<60 ng g-1) THg concentrations in soils compared to other studies (>300 ng g-1) of MeHg in rice fields. Rice grain MeHg and THg concentrations were among the lowest reported in the literature and well below levels of concern for human health. These results suggest that the fields studied here have comparatively low levels of Hg contamination over all.

MeHg and THg concentrations in drainage water were similar to irrigation water in the growing season, but fallow season drainage water had elevated MeHg and THg concentrations. Based on surface water budgets, fields were net MeHg and THg importers during the growing season and net exporters during the fallow season. During the fallow season, the two fields exhibited different temporal patterns in drainage water MeHg concentration. One spiked early and then decreased while the other increased

over the flooded period. These results show that the period of concern for MeHg export from rice fields is during the fallow season.

Study 2: Alternate wetting and drying as a MeHg management practice

Alternate wetting and drying (AWD) is a rice water management practice that has been shown to provide multiple benefits including reduced water use, methane emissions and arsenic accumulation in rice grain. However, previous studies of MeHg production suggested AWD might increase MeHg, while other studies suggested the opposite. We conducted a controlled, replicated experiment to determine how alternate wetting and drying water management (AWD) affects MeHg in rice systems.

Two treatments, AWD and continuously flooded control (CF), were compared in a randomized complete block design field experiment. Each treatment was replicated 3 times in plots 0.2 ha in size. Beginning after canopy closure (~50 days after planting), irrigation of AWD plots was stopped. After soil in AWD plots dried to 35% volumetric water content, plots were re-flooded. This procedure was repeated once for a total of two drying cycles in AWD plots. Continuously flooded control plots (CF) were flooded throughout the growing season. Water, soil and plant samples were collected throughout the growing season and fallow and analyzed for MeHg and THg.

Compared to CF, AWD resulted in significant reductions in MeHg concentrations in soil, surface water and rice grain. Rice yields in AWD plots were not different from yields in plots under conventional continuous flooded management. These results suggest AWD may be an effective way to decrease problems associated with MeHg production in rice fields. Since AWD also reduces water use, greenhouse gas emissions and rice grain arsenic, while maintaining yields, it has potential for adoption by growers.

INFORMATION TRANSFER/OUTREACH PROGRAM:

The results of this project were made available to a wide variety of stakeholders. Outreach efforts included poster presentations at the annual Rice Field Day at the Rice Experiment Station in Biggs, CA, and at the workshop Revisiting the 2003 Mercury Strategy for the Bay-Delta Ecosystem. Presentations were given to the Delta Tributaries Mercury Council, a local stakeholder group that includes regulators, environmental groups and industry leaders. These results were also presented to a scientific audience at the annual meeting of the Agronomy, Crops and Soils societies.

Debris flow and debris basin management impacts on water quality

Basic Information

Title:	Debris flow and debris basin management impacts on water quality
Project Number:	2016CA364B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	44
Research Category:	Water Quality
Focus Category:	Water Quality, Management and Planning, Water Use
Descriptors:	None
Principal Investigators:	Andrew Gray

Publications

1. Gray, Andrew. 2017. The Gray Lab: Watershed Hydrology, Geomorphology, Sedimentology, Water Quality. http://andrewgray.ucr.edu/
2. Leeper, Robert J; Barth, Nicolas C, Gray, Andrew B. December 15, 2016. Analyzing the occurrence of debris flows and floods in a small watershed two years after a wildfire, San Gabriel Mountains, California. Abstract H43G-1550. 2016 Fall Meeting, AGU, San Francisco, CA.

RESEARCH PROGRAM:

Little is known about the quality and quantity of sediments exported from burned areas instrumented with debris basins. The research plan to approach this knowledge gap was to employ integrating hydro-meteorological monitoring of debris flow events with debris basin operations and suspended sediment monitoring to develop a better understanding of the changing conditions required to initiate debris flows with system rebound after wildfire, and to characterize the effects of debris flows on sediment mediated water quality. Research was conducted in the watersheds of the Englewild and Las Lomas canyons: steep headwater catchments situated above the cities of Glendora and Duarte, CA that experienced the Colby (1/2014) and Fish (6/2016) wildfires, respectively. To examine the timing and intensity of precipitation events required to trigger debris flows, both study regions were instrumented with multiple high-resolution rain gauges and self-contained pressure transducers installed in bedrock channel beds.

The Englewild debris basin drainage channel was outfitted with a hydrologic gauging and sampling station to monitor water and sediment export from the basin, which included instrumentation to measure stage, average flow velocity, turbidity, and an automated water sampler. Gauging and sampling from the Las Lomas debris basin drainage pipe was not possible due to access issues. Subbasins of both catchments were surveyed at high resolution (10^{-1} to 10^{1} cm scale) using TLS and UAV technologies. Resurveying in the Las Lomas study area was performed after each significant (i.e. debris flow triggering) storm. Hillslope, channel and exported sediments were characterized for particle size distribution, carbon content, and fallout radionuclide (^{210}Pb, ^{137}Cs, and ^{7}Be) abundance.

Very little debris flow activity was observed in Englewild Canyon during water years 2016 and 2017, despite five minute duration rainfall intensities surpassing know post-fire debris flow initiation thresholds (Leeper et al., 2016). In contrast, the more recently burned Las Lomas catchment produced debris flows at even lower thresholds than previously established. Evidence from these portions of the study will be used to modify existing approaches to assessing debris flow risk potential in post-wildfire scenarios. Also as a result of system rebound, including breakdown of hydrophobic layers and increased vegetative effects, the Englewild Debris Basin drainage channel experienced only very low flow levels and minor episodes of sediment transport during water year 2017. Las Lomas and Englewild surveying and sediment sampling results are in process, but show promising indications of new evidence to support the identification of dominant erosional regimes in these landscapes, and how they shift after wildfires. Sediment composition analyses are in process.

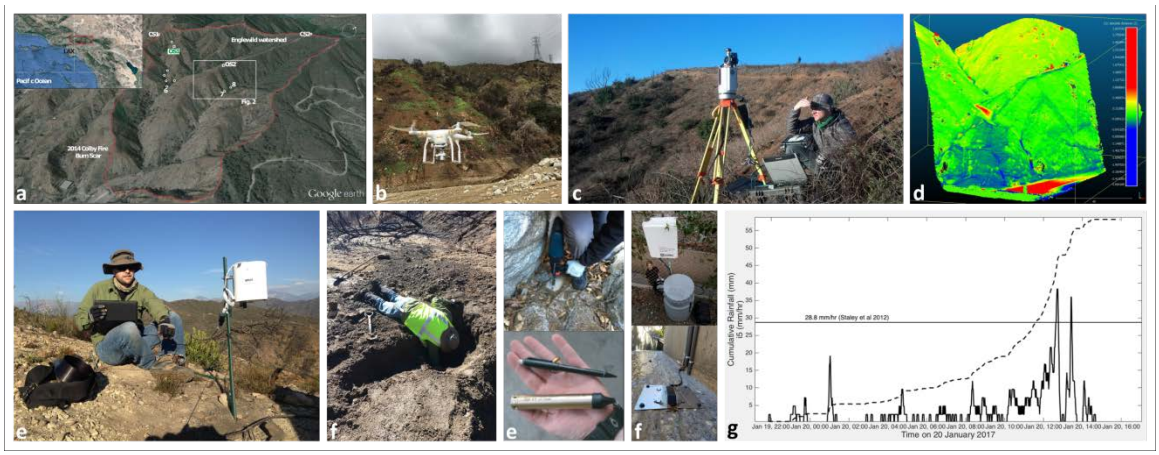

Figure 1. (a) Englewild Canyon field site, (b-d) 3-D surveying and DEM development, (e-g) hydro-meteorological monitoring and sediment sampling (images from R. Leeper, N. Barth and A. Gray).

INFORMATION TRANSFER/OUTREACH PROGRAM:

Preliminary results of this study have been communicated at the American Geophysical Union 2016 Fall Meeting (Leeper et al., 2016), on the PI's website (Gray, 2017), and through coverage of our work by the UC ANR water sciences blog. Two journal articles are currently in preparation.

The Influence of Incubation Temperature on Aerobic Swimming Performance of Juvenile Salmonids

Basic Information

Title:	The Influence of Incubation Temperature on Aerobic Swimming Performance of Juvenile Salmonids
Project Number:	2016CA365B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	44
Research Category:	Biological Sciences
Focus Category:	Climatological Processes, Hydrology, Water Use
Descriptors:	None
Principal Investigators:	Amanda I Banet

Publications

There are no publications.

RESEARCH PROGRAM:

The goal of this project is to provide an ecologically relevant measure of how incubation temperature influences Pacific salmon at later life stages. Specifically, this project examines how increases in incubation temperature affect juvenile aerobic swimming performance after hatch by exploring the following hypotheses.

H1) Fish incubated at high temperatures will have a lower aerobic scope than those incubated at low temperatures.

H2) Increased water temperature during aerobic swimming will more negatively affect the aerobic performance of fish incubated at high temperatures, as compared to that of fish incubated at low temperatures.

To test these hypotheses, we have incubated salmonid eggs at three different temperatures that represent the range of temperatures they might experience in nature. After the eggs hatched and fish progressed through the alevin (larval) stage, fish from all treatments were transferred to holding tanks where they continued to grow in preparation for aerobic trials. We began the experiment with *Oncorhynchus tshawytscha* (Chinook salmon) eggs, but we encountered struggles with antibiotic resistant *Flavobacterium psychrophilum* (cold-water disease), a gram-negative bacterial disease that affects salmonids.

After consultation with US Fish and Wildlife and California Fish and Wildlife, we were able to obtain *Oncorhynchus mykiss* (steelhead/rainbow trout) eggs to use in the project in order to ensure the presence of the disease would not affect the results of the study. The nature of this project (e.g. the timing of spawning and length of incubation and rearing) means we do not yet have results to report. We look forward to sharing our findings in the year 2 report.

Graduate student Nick Balfour palpates the abdomen of a gravid female salmon to collect eggs for the project.

Eggs beginning to hatch at the end of incubation. Fish at this stage of development are called alevins, and receive nutrients from the yolk sac attached to their body.

INFORMATION TRANSFER/OUTREACH PROGRAM:

The presence of this project on the CSU Chico campus has allowed opportunities for several community outreach programs. In year one of the project we invited three different community groups made up of K-12 students and their parents to visit the lab and learn about the importance of water in California, fish biology, and the science that motivates the project. Tours were catered to the age group visiting.

Undergraduate researcher Linda Drobatz (center) talks to local elementary school children about the importance of water and temperature for salmon.

Soil Survey Decision Support Tools for Water Resource Sustainability and Agricultural Productivity

Basic Information

Title:	Soil Survey Decision Support Tools for Water Resource Sustainability and Agricultural Productivity
Project Number:	2016CA366B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	44
Research Category:	Water Quality
Focus Category:	Agriculture, Water Quality, Irrigation
Descriptors:	None
Principal Investigators:	Anthony T. O-Geen

Publications

1. O'Geen, A.T., Mike Walkinshaw, Dylan Beaudette, In press. SoilWeb: A multifaceted interface to soil survey information. Soil Science Society of America Journal doi:10.2136/sssaj2016.11.0386
2. Salls, Wilson, 2016, Grazing the surface: Estimating erosion potential across California's rangelands M.S. Dissertation, Soils and Biogeochemistry Graduate Group. University of California, Davis, CA. 50 pp.
3. Saal, Mathew, 2014, Repackaging Soil Survey into a Decision-Support Tool for Agricultural Groundwater Banking in California. M.S. Dept. of Land, Air and Water Resources, College of Agriculture and Environmental Sciences, University of California, Davis, CA, p. 1-36.
4. Warnert, Jeannette, Researchers study farm field flooding for aquifer recharge. 2016. http://ucanr.edu/blogs/anrnews/index.cfm?tagname=Roger%20Duncan
5. Parsons, Cecilia, 2016. A dozen UC experts tell about variety of agricultural research. Ag Alert 2/17/2016.
6. Weinstock, Dave. 2016. Soil-mapping tools available to growe3rs. Good Fruit Grower Magazine http://www.goodfruit.com/soil-mapping-tools-available-to-growers/
7. O'Geen, A.T. 2/9/2016, Exploring managed flooding on farms for groundwater banking. World Ag. Expo. Media briefing.
8. O'Geen, A.T. 2/17/2016, Potential for increasing groundwater recharge on agricultural land. Monterey County Cooperative Extension Grower Workshop.
9. O'Geen, A.T. 3/1/2016, Interactive online soil survey decision support tools and apps. Workshop with International programs, NGO's and UC faculty.
10. O'Geen, A.T. 3/4/2016, Creating a data driven nitrate leaching hazard index. Workshop for consultants.
11. O'Geen, A.T. 3/8/2016, Exploring groundwater recharge. Russel Ranch Field Day for growers.
12. O'Geen, A.T. 7/7/2016, Soil Health in California's Annual Rangelands. Grazing land Soil Health workshop; state of the science hosted by NRCS and ARS.
13. O'Geen, A.T. 9/23/2016, Expert panel on groundwater: Making it count. Society of Environmental Journalists.

RESEARCH PROGRAM:

In the near future, demand for a clean and dependable water supply will increase exponentially as a result of population growth, climate change, and environmental needs. As the largest user of California's fresh water supply, agriculture is at the heart of this dilemma, and will be subject to a great deal of policy, regulation and possibly incentives to solve water resource problems. California growers are just now witnessing this eventuality with the implementation of the irrigated lands waiver program and the Sustainable Groundwater management Act. We propose that the foundation to CA's water sustainability solutions are place based, and thus, can be realized through decision support tools that document the soil landscape's capability to filter water and accommodate deep percolation. This report focuses on three subprojects: 1. A data driven nitrate leaching hazard index; 2. A drought response tool for irrigated agriculture; and, 3. An assessment of soil erosion potential in annual rangeland.

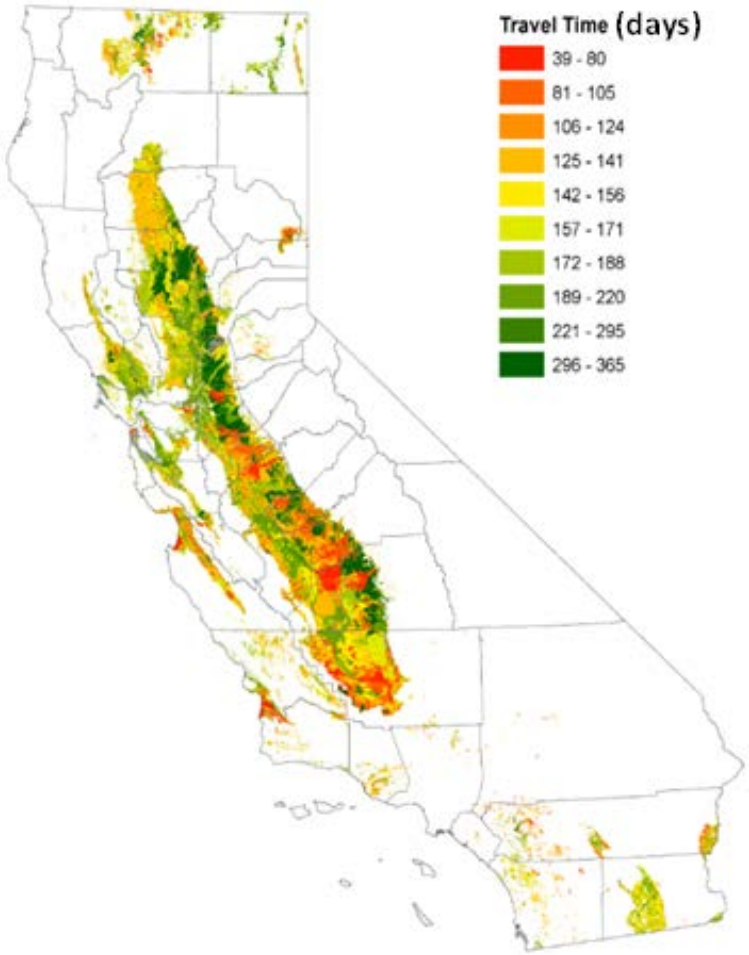

Figure1. Relative differences in nitrate travel times using a modeled tracer experiment.

Nitrate leaching tool: We created a nitrate leaching potential scenario for all soils in agricultural regions (cropland) of the State. This scenario was modeled to evaluate the soil's intrinsic susceptibility to nitrate leaching considering only soil properties. We ran a process based model (HYDRUS 1-D) for 5685 soil profiles. The simulation time was 1 year and we assumed constant rainfall of 1 cm/day and a nitrate pulse application of 1 Mu/day (Mu: mass unit) for 10 days. From this, we calculated solute travel times to a depth of 1.5 m, defined as the time needed for 95% of the total applied mass to reach the bottom of the profile (Figure 1).

Next, we investigated the effect of climate on nitrogen leaching to evaluate the fate of residual nitrate in soils after harvest. We defined seven climate zones in order to estimate differences in evapotranspiration and precipitation across CA for the period of 1/1/2000 until 12/31/215. We conducted 39,795 Hydrus simulations (7 climate zones x 5,685 different soil profiles) for a 16-winter-year period. This exercise can be considered a scenario where winter precipitation drives the movement of residual soil nitrate after harvest when uptake is low. Figure 2 shows the spatial distribution of annual nitrate mass leached beyond 1.5 m. As expected, the results show that climate strongly influences the movement of water and nitrate. Vulnerable areas with values of higher mass leached are found in northern regions where precipitation is higher (Figure 2).

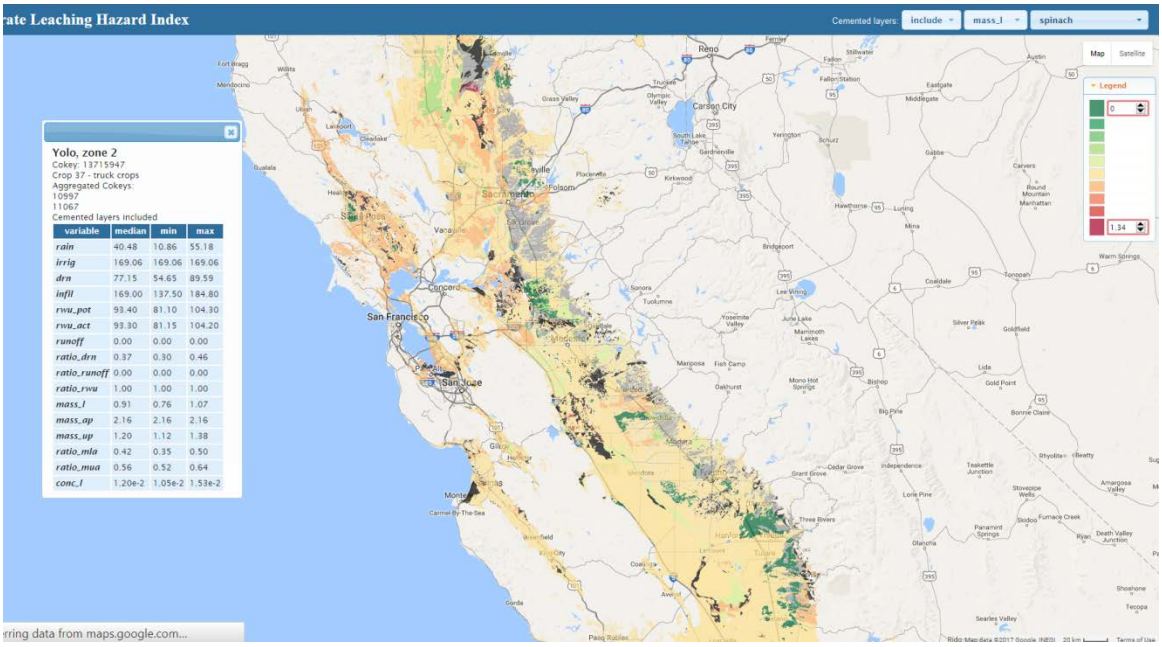

Figure 2. Preliminary output from the nitrate leaching tool showing mass (mg cm^{-3}) of nitrate leached under spinach.

However, areas with high nitrate concentration in pore water correspond with the dryer portions of the State (Figure 3). The reason is that while less mass is leaching from the soil profile it is diluted by less water, which raises the concentration of nitrate in pore water. From a risk assessment point of view, this highlights the importance of nitrate pore water concentration in regions where groundwater recharge is low.

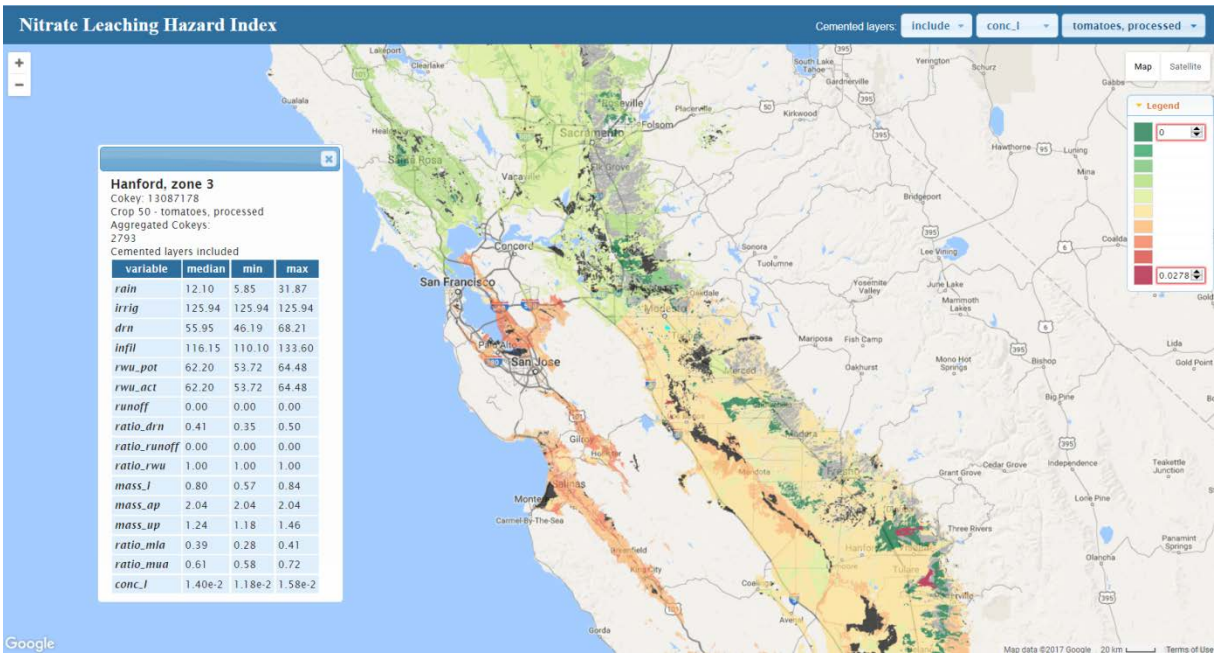

Figure 3. Preliminary output from the nitrate leaching tool showing output nitrate concentration leached for tomatoes.

Allowable depletion: *Green* water is the soil-stored water from natural rainfall that is potentially available to plants. Provision of 'green' water is a soil ecosystem service that can reduce reliance on 'blue' water in irrigated agriculture and reduce contamination of surface and groundwater from over-irrigating. One technique for making use of green water in irrigated agriculture in California is to withhold irrigation at the beginning of the growing season until soil-stored water has been depleted to a point just before the onset of possible plant water stress. This proportion of plant available water is called the *allowable depletion* in irrigation management. Our initial and conservative statewide estimates suggest that by delaying time to first irrigation, over 1 million acre-ft of green water can be utilized, resulting in a similar reduction in the amount of water used for irrigation later in the season (Figure 4).

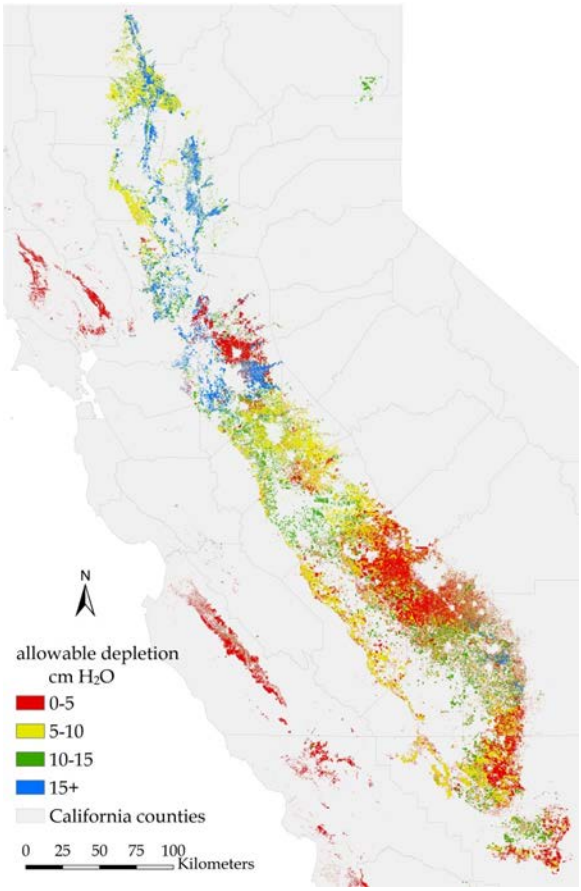

Fig. 4. Allowable depletion estimates generated using storage capacity of soils, the distribution of key perennial crops (Walnuts, alfalfa, Almonds and grapes) their associated rooting depth.

Rangeland erosion: We found that over the entire 14.8 million acres of rangeland, modeled erosion exceeded the erosion tolerance factor in only 174,733 acres (0.012%) in the heavy grazing/low cover scenario, 79,506 acres (0.005%) with moderate cover scenario, and 28,990 (0.002%) acres for light grazing high cover scenario. Findings suggest residual dry matter recommendations are adequate for minimizing erosion. In addition, managing grazing to mitigate erosion is most effective when targeted at areas of high vulnerability.

INFORMATION TRANSFER/OUTREACH PROGRAM:

My information transfer program involves the communication of science via written, oral and internet based communications. During this reporting period I performed 7 presentations. These addressed stakeholders and policy makers from diverse perspectives. Internet-based information delivery is also a major focus of my program. The apps developed by my program (https://casoilresource.lawr.ucdavis.edu/soilweb-apps/) receive hundreds of visits per day.

Information Transfer Program Introduction

Information transfer program is included on a project by project basis in the previous section.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	5	0	0	0	5
Ph.D.	6	0	0	2	8
Post-Doc.	14	0	0	3	17
Total	27	0	0	5	32

Notable Awards and Achievements

2016CA365B, Amanda Banet: In addition to the two graduate students funded by this work, this research has provided educational opportunities to 26 undergraduate students, who either participated in the project as undergraduate researcher volunteers (9 students) or learned about the biology driving the project as part of their coursework (17 students). One undergraduate researcher was able to get her own funding to conduct a complementary study of thermal tolerance using the same experimental fish.

2016CA364B, Andrew Gray: A relationship with the LA County Department of Public Works has been furthered during the study period, which has facilitated access to the study watersheds, their debris basins, and some drainage structures. This relationship will help support further studies in the region, and facilitate future information transfer to operations personnel involved in debris flow management. Collaboration has been fostered between the PI and Assistant Professor Nicolas Barth, UCR Department of Earth Sciences through shared advising of Robert Leeper, the first graduate student funded in part by this project. A new collaborative investigation into the carbon dynamics of chaparral landscapes involving the PI and Associate Professor Jeff Hatten, Oregon State University Department of Forestry has been made possible by the sediment sampling efforts involved in this study.

2016CA361B, Clarissa Nobile: We are currently putting together a manuscript that will include our findings over the last two years of this project.

2016CA358B, Joseph Blankinship: 1. Awards: An environmental scanning electron microscope (ESEM) image of xanthan gum strands in soil won Dr. Blankinship 2nd Place in the University of California Santa Barbara 2015 Art of Science Competition. Mr. Henry Morse (undergraduate assistant) was a finalist at the UC Santa Barbara Research SLAM designed to foster science communication skills. 2. Achievements: First, this idea actually worked: amending soil with xanthan gum lead to a 40% increase in crop water-use efficiency and moderated nitrogen losses. Second, this project was very well received at the ASA/CSSA/SSSA Tri-Societies 2016 Annual Meeting. After his presentation, Dr. Blankinship received many questions and research collaboration interests. The approach/results were clearly novel and intriguing to the broader community. 3. Collaboration: After the Tri-Societies meeting, Dr. Blankinship was contacted by Judith Fitzpatrick (Prolific Earth Sciences) and James Sittilo (Ecological Landscape Management) to discuss the possibility of testing soil amendment of xanthan gum at the field-scale in parks in the eastern US in erosional areas and in sandy soils that need improved water retention during drought conditions. 4. Broader Impacts: This project has contributed to a deeper understanding in the Santa Barbara community of why soil organic matter is so important for drought resilience. Collaborations have been built with the Cachuma Resource Conservation District, the Chamberlin Ranch, as well as Santa Barbara County government agencies (e.g., waste management and air pollution control) and non-profit organizations (e.g., Santa Barbara Foundation). The common goal is to increase soil carbon storage and water-holding capacity by amending agricultural soils with municipal green waste (i.e., compost). This is a more cost-effective strategy than amending soils with xanthan gum, but may very well encourage the same mechanisms of water and nutrient retention.

2016CA366B, Anthony O'Geen: The attention generated for the Soil Agricultural Groundwater Banking index led to a briefing of the Governor's Office of Planning and Management, Senior Policy Advisor to Governor, and Governor's Community and Rural Affairs Advisor.

2016CA363B, Bruce Linquist: There is a total maximum daily load (TMDL) in place for MeHg in the Sacramento River Watershed. Data from this study provides valuable information to regulators about how much MeHg is in rice field drainage water and will likely influence regulatory decisions related to meeting the TMDL requirements. Importantly we found that MeHg concentrations and loads in the Sacramento Valley were significantly lower than those found in the Delta (where previous studies had been conducted).

AWD may be utilized to reduce MeHg concentrations not only in the Sacramento Valley, but also in rice growing areas where Hg is a concern worldwide. MeHg in rice grain is an important human health concern in areas with a legacy of Hg pollution, and AWD may prove to be a valuable tool for producing healthier rice in those areas.

2016CA362B, Igor Lacan: a. I discovered that the concerns over trees in bioswales have become more widespread: San Francisco, for example, intentionally will not include trees in their new bioswales until 2018 (and I thus needed to replace them); Berkeley is not including trees in future bioswales.

b. I secured three additional study partners: city of Berkeley (to replace San Francisco), City of San Carlos, and City of Burlingame.

c. I secured an additional grant, which has allowed me to expand this study in scope and in duration: from USDA Forest Service via the National Urban and Community Forestry Advisory Council (NUCFAC). The new grant has allowed me to expand the number of study sites in the original partner cities, and to equip with soil moisture sensors the bioswales in the new partner cities, as well as to extend data collection for an additional two years. Please note that the two grants are completely separate (sites, equipment, my time, etc.) and that the NIWR grant is not in any way used for the matching requirements in the NUCFAC grant.

d. Preliminary results from the soil moisture sensors suggest that excessive water is not likely to be a problem (as the duration of waterlogged period is relatively short); however, water deficiency may be a problem: sensors at 30 cm depth indicate very low water content (

e. A recognition that bioswale soils and design may have to be modified for optimal plant performance is becoming more common, as evidenced by the workshop I co-organized in June 2016 on bioswale soils (in Oakland, CA) – it was attended by over 40 people.

2016CA359B, Arnold Gwen: Because we have not finished data collection and analysis, there are few notable achievements to report. Perhaps the most notable achievement thus far is the fact that, during the reporting period, the data collection process has been substantially fueled by approximately 14 students (mainly undergraduates) seeking to learn more about HVHF policy and academic/policy-relevant research. Some of these students are interns working for research credit, others are volunteers, and a handful of others are paid from various grants.

The students gain first-hand experience with research as they contact municipal officials to file and follow up on CPRA requests, analyze public meeting minutes, call survey and follow up with survey recipients, and track and organize survey returns and data. One undergraduate student, Eleni Jacobson, has focused exclusively on the California research and has played a key role in survey data entry, interviewee identification, secondary source data collection and analysis, and actual completion and transcription of interviews.