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[Manage Financials](#)
[Program Income Reporting](#)
[Grantee Cash Management Section Contacts](#)
[Administration](#)
[Lookup NSF ID](#)

Preview of Award 1331940 - Annual Project Report

[Cover](#) |
[Accomplishments](#) |
[Products](#) |
[Participants/Organizations](#) |
[Impacts](#) |
[Changes/Problems](#)

Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1331940
Project Title:	The Eel River Critical Zone Observatory: exploring how the critical zone will mediate watershed currencies and ecosystem response in a changing environment
PD/PI Name:	William E Dietrich, Principal Investigator James K Bishop, Co-Principal Investigator Stephanie M Carlson, Co-Principal Investigator Mary E Power, Co-Principal Investigator Sally Thompson, Co-Principal Investigator
Recipient Organization:	University of California-Berkeley
Project/Grant Period:	10/01/2013 - 11/30/2020
Reporting Period:	10/01/2018 - 09/30/2019
Submitting Official (if other than PD/PI):	William E Dietrich Principal Investigator
Submission Date:	10/18/2019
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	William E Dietrich

Accomplishments

* What are the major goals of the project?

The major goals of the Eel River CZO as outlined in our Management plan are to answer these four questions:

1. Does lithology control rock moisture availability to plants and therefore overall resilience of vegetation to climate change in seasonally dry environments?
2. How are solute and gas effluents from hillslopes influenced by biota in changing moisture regimes?

3. What controls the spatial extent of wetted channels in the channel networks of seasonally dry environments?
4. Will changes in critical zone currencies induced by climate or land use change lead to threshold-type switches in river and coastal ecosystems?

Additionally, we propose to develop a numerical platform – the Atmosphere-Watershed-Ecology-Stream and-Ocean Model (AWESOM) to synthesize findings from smaller scale studies, couple the different critical zone subsystems together, and explore the long-term and large-scale consequences of the dynamics of the critical zone in the context of changes in climate, land use, and water management policy.

*** What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

Question 1: Does lithology control rock moisture availability to plants and therefore overall resilience of vegetation to climate change in seasonally dry environments?

See attached for complete description of Question 1 activities from 2018-19, including:

- 1) Vadose Zone Monitoring System and sampling campaigns (Collaborator Professor D. Rempe)
- 2) Downhole geophysics (Collaborator Professor D. Rempe)
- 3) Rancho Venada (Collaborators Professors D. Rempe, D. Dralle, and J. Hahm)
- 4) Deuterium Tracer Experiment (Collaborators Professors J. Hahm and D. Rempe)
- 5) Plant Available Nitrogen
- 6) Fluid mobility and shale weathering (Collaborator Professor J. Druhan)

Question 2: How are solute and gas effluents from hillslopes influenced by biota in changing moisture regimes?

- 1) Dry-season changes in soil carbon cycling

Dry season changes in soil carbon cycling is rarely documented and is poorly known. The east-west orientation of the ridge across Rivendell allows a comparison of soil carbon dynamics on north and south slopes. Soil samples have been collected at approximately 2-month intervals to quantify the water-soluble and microbe-available soil carbon fractions. Soil cores are taken to a depth of 60 cm and analyzed for a suite of edaphic features. Chemical analysis of the water-soluble fraction is being used to identify seasonal changes in the source of this carbon. Radiocarbon measurements are being made of the microbe-available fraction to quantify changes in the historical cycling rate of this carbon. By coupling these measurements to indicators of hydraulic redistribution, our goals are (a) to track dry-season changes in the stock, transport, and stabilization of the most mobile/available soil carbon fraction, and (b) to link these observations to tree canopy composition and root hydraulics.

- 2) Bacterial metagenomics

Microbial communities in soil and underlying weathered rock (saprolite) contain a huge variety of bacteria, most of which have not been investigated in terms of their potential to produce secondary metabolites. These molecules could shape community interactions and impact biogeochemical processes, including mineral dissolution. Soils and saprolite were sampled from three sites in northern California with varying vegetation and bedrock characteristics. Metagenomic sequencing of these samples

allowed for the reconstruction of thousands of microbial genomes containing diverse biosynthetic gene clusters (BGCs) for the production of secondary metabolites. The amount and types of BGCs present in these genomes is shown to be distinct at the phylum level. Chloroflexi, a well-studied phylum not previously linked to biosynthetic potential, encode large numbers of BGCs and key biosynthetic domains. Surprisingly, a few BGCs were found to be encoded in the genomes of Candidate Phyla Radiation (CPR) bacteria, which are considered to be obligate symbionts due to their reduced genomes. Specifically, a Levybacteria genome encodes proteins for synthesis of an azoline-based compound, another is predicted to be capable of producing a lantipeptide, and a Saccharibacteria likely produces a terpene-based organic. These capacities have not been reported previously, but appear to be present in diverse CPR across environments. In addition, environmental characteristics such as soil depth and overlying vegetation type are shown to affect biosynthetic potential. Genomes enriched in shallow and grassland soils contain more BGCs than those in deep or tree-covered soil. However, the types of BGCs present across soil environments remain relatively consistent. Overall, terpenes, NRPS/PKS clusters, and bacteriocins are the most prevalent. Small molecules produced by diverse soil bacteria may mediate inter-organism interactions and impact mineral dissolution reactions. These compounds could also have value as new antibiotics or other therapeutics. This work was submitted as Master's thesis by A. Sharrar.

Question 3: What controls the spatial extent of wetted channels in the channel networks of seasonally dry environments?

1) Travel Time Distribution Model (Collaborators Professors J. Hahm and D. Dralle)

Travel time distribution functions for runoff have recently attracted much interest and debate. Our monitoring of stable isotopes in rainfall and runoff at Sagehorn-Russell Ranch (in the mélange) and at the Angelo reserve have provided data to compare and contrast travel time distributions functions and to compare these functions with documented travel pathways and reservoir dynamics. Data analysis and modeling are underway.

Question 4: Will changes in critical zone currencies induced by climate or land use change lead to threshold-type switches in river and coastal ecosystems?

1) Food web phenology (how stream temperature and flow levels influence salmon foraging)

In 2019 data were collected on the interaction between low flow (spring to fall) hydrology and food web in tributary streams – specifically to investigate their effects on juvenile salmonid foraging and behavioral response. Two streams, a perennial shaded stream, and an intermittent sunnier stream, were compared. Some of this work is directed at documenting the possible benefit to fish of flow augmentation (from water stored behind dams).

2) Pikeminnow in the South Fork Eel River (how stream temperatures influence the spread of introduced fish)

Summer 2019 field measurements revealed that Pikeminnow, an introduced predatory fish, to migrate upstream earlier than previous years, likely due to higher river temperatures caused by a warmer-than-average late spring. The high flows also reduced the population of Pikeminnow. These data show that the spread of this salmon eating predatory fish depends on stream temperature and flood flows, both of which are mediated by the critical zone.

3) Functional Response Experiment (how stream temperature influences predation)

In the summer 2019, field experiments were conducted to test how temperature influences the predatory interaction between larval odonates (dragonflies) and juvenile California roach. In this case, it is the dragonfly larvae living in the water that are active predators on the abundant small fish (roach). This experiment was conducted at 3 river locations that differed in temperature. Preliminary results indicate that temperature could influence the two organisms in different ways, that in turn influence their interaction. At low temperatures dragonflies were more successful at catching larval roach (higher strike success), and at high temperatures dragonflies might be able to consume more roach in a given time, if they can catch them.

4) Refugia model (stream temperature and salmon survival)

Cold tributary streams can provide cool water refuges in warmer mainstem rivers. A simple scaling model was developed that can predict hourly estimates of cold zones, and is highly flexible and not species specific. The model is a step in the direction of using mechanistic-based models for predicting ecological outcomes. Stream temperature data from three summers at locations on the SF Eel were compared with data from Klamath River collected by collaborators. The geometry, shape, persistence, and temporal variation of refugia at tributary confluence sites were quantified. These data will be used as reference points to guide a coupled runoff- stream temperature model for the South Fork Eel.

Question 5: AWESOM: The Atmosphere-Watershed-Ecology-Stream and-Ocean Model

Data analysis work is underway to understand mortality rates of trees at the species level, and integrating findings into coupled climate -vegetation model.

Specific Objectives:

Milestone 1: Does lithology control rock moisture availability to plants and therefore overall resilience of vegetation to climate change in seasonally dry environments?

1.1 Monitor vadose zone moisture dynamics

1.2 Explore controls on stable isotopes in storage reservoirs and trees

1.3 Monitor sap flow, soil moisture, and meteorology on Rivendell south facing slope

Milestone 2: How are solute and gas effluents from hillslopes influenced by biota in changing moisture regimes?

- 2.1 Monitor plant available forms of N through the critical zone
- 2.2 Monitor dry-season changes in soil carbon cycling
- 2.3 Explore genome-resolved analysis of subsurface rhizosphere community
- 2.4 Continue periodic sampling of subsurface gas in the critical zone
- 2.5 Collect and analyze VMS samples from Rivendell, as well as rainfall and runoff samples from Rivendell and Sagehorn

Milestone 3: What controls the spatial extent of wetted channels in the channel networks of seasonally dry environments?

- 3.1 Model critical zone dependent runoff and stream temperature
- 3.2 Collect high frequency concentration-runoff data at Sagehorn

Milestone 4: Will changes in critical zone currencies induced by climate or land use change lead to threshold-type switches in river and coastal ecosystems?

- 4.1 Upscale tributary refugia model to entire watershed
- 4.2 Quantify the phenology of food webs in salmon bearing streams
- 4.3 Document temperature controls on the spread of invasive fish

Milestone 5: Synthesis Modeling (the Atmosphere-Watershed-Ecology- Stream-Ocean Model)

- 5.1 Develop further the 1-D vadose zone model based on observations on the south slope
- 5.2 Advance coupling of model components of AWESOM
- 5.3 Advance the coupled model for stream flow and temperature

Significant Results:

1.1 Vadose zone moisture dynamics is monitored via repeat neutron probe surveys of all wells, moisture probe measurements along 10 ports in the two 16 m deep bore holes of the VMS system, several time domain reflectometry moisture profiles, and by an index measure from simple moisture vertical profiling probes. These data have revealed that the soil vadose zone and rock moisture vadose zone wet up nearly simultaneously as wetter rains arrive. In both the soil and rock moisture zone hundreds of mm of rain must occur for the moisture content to cease rising, where behavior like field capacity develops

1.2 Tracer injection experiment has been initiated and follow up measurements will be used to track moisture into trees and to great depth.

1.3 Ongoing, no significant results

2.1 Ongoing, no significant results

2.2 Measurements this year show that the quantity and chemistry (based on ¹H-NMR) of mobile and microbe-available carbon varies across the dry season in depth-dependent and vegetation-dependent ways. The organic and shallow mineral layers in particular experience a significant increase in minimally-processed carbon compounds during the driest portion of the summer season, likely due to moisture limitation of microbial respiration.

2.3 Some bacterial phyla not previously linked to biosynthetic potential have members whose genomes contained many biosynthetic gene clusters at the CZO. Surprisingly a few of these clusters were found in CPR(candidate phyla radiation). Some phyla at the CZO have clusters for producing types of microbial products which they hadn't previously been known to. Across environmental variables, genomes enriched in shallow and grassland soils contained more biosynthetic gene clusters than those in deep or tree-covered soil.

2.4 Radiocarbon characterization confirms that across dry and wet seasons, the CO₂ produced at depth is modern, and thus sourced from the surface through rhizodeposition of the mature forest ecosystem. See discussion under Question 1 (6) for details.

2.5 Samples collected every two weeks have documented distinct and systematic solute and stable isotope trends with depth through the vadose zone.

3.1 Ongoing, no significant results

3.2 Sample collection show that in Elder Creek (that drains Rivendell), which is bordered by hillslopes underlain by deep critical zones, shows very little concentration with discharge due to solute evolution in the vadose zone. Samples collected from runoff in the mélange at Dry Creek where overland flow is common in winter shows that concentration varies greatly with runoff.

4.1 Published results show that characteristics of cold zones identified as thermal microrefugia are not robust to the choice of microrefugium definition. Alternative observation and classification approaches may be needed to characterize cold zones.

4.2 see results in Question 4 above.

4.3 see results in Question 4 above.

5.1 Ongoing, no significant results

5.2 Ongoing, no significant results

5.3 Ongoing, no significant results

Key outcomes or Other achievements:

Critical zone storage and vegetation resilience to drought

When we set out to compare our two primary monitoring sites, "Rivendell" in the Coastal Belt bedrock of shales and sandstones and "Sagehorn" in the Central Belt of mélange, we were focused on explaining why Rivendell is an evergreen forest of needle and broadleaf trees and Sagehorn is a deciduous oak savannah with south facing slopes mostly grass covered. These two sites, just 20 km apart receive nearly the same rainfall. We learned, and have reported in previous annual reports, that this difference

was due to the depth of development of the critical zone. In seasonally dry environments, vegetation must rely on critical zone moisture storage to survive. The deep critical zone at Rivendell holds annually ~ 300 mm of moisture that is transpired by the trees, whereas the shallow critical zone at Sagehorn holds ~ 100 mm of moisture, enough to support grass. During our monitoring period, California was struck by an exceptional drought in the combination of reduced rainfall and global warming amplified elevated temperatures- a double stress on plants. Perhaps 129 million trees died between 2012 and 2016 due to drought stress. None of the Rivendell trees or sparsely distributed Sagehorn trees died. This led our team to ask why the trees survived at our site.

We found that although the annual rainfall dropped to as low as 50% of the average in 2014, that rainfall still exceeded the storage capacity of the subsurface. This means that the stored water that the trees then live on for nearly 6 months was unaffected by the drought: the rainfall exceeded the storage capacity. This observation suggested that instead of focusing only on the rainfall amount and the physiological properties of trees or the thickness of the soil, we should document the ratio of rainfall to storage capacity. Where rainfall doesn't dip below the storage capacity, even in a very dry year, the vegetation will not experience the drought. This ratio can exceed 1 (and thus be drought resilient) by having a thin critical zone (such that even in annually dry places the reduced rainfall of a drought still restores the storage for the summer) (the Sagehorn case) or a thick critical zone with high storage, but sufficient rainfall that doesn't drop below that storage amount even in drought (our Rivendell case).

Our team (see Hahm et al, 2019 in publication list) then analyzed all the USGS runoff data in California to compute the likely winter storage (which is equivalent to the rainfall minus winter evapotranspiration) that then becomes available for spring and summer growth. They avoided areas with snow because snow adds the complication that storage occurs transiently above the soil and thus is difficult to document and is independent of the critical zone depth. Hahm et al. showed that in streams such as Elder Creek (which drains the coastal belt and our Rivendell study site) every year the precipitation was sufficient to recharge the storage. In contrast, they documented that in a majority of watersheds, wetter years led to more storage, indicating that the critical zone storage was commonly not fully "charged" in most years. They found that satellite-based "enhanced vegetation index" (EVI), a measure of plant productivity, increased in years with rainfall, but saw no annual change in EVI where the subsurface storage was always less than the rainfall. *These findings led Hahm et al. to propose that vegetation was relatively resilient to drought where the storage capacity was low relative to the winter rainfall.*

These findings require rethinking how we might predict vegetation response to drought. It is a reasonable argument to propose that trees should be more drought resilient where there is a deep, porous critical zone that can hold large quantities of water. Then, trees die in a drought where they have developed on shallower, less water storing areas. But our observations and analysis now indicate that trees are more likely to die where the annual rainfall in successive years falls below the subsurface water storage capacity. Currently, estimates of moisture storage relies on published soil data. Our work demonstrates that rock moisture (in the weathered bedrock) may greatly exceed soil moisture, and be key to survival of trees during the long dry summers. Hence, the rainfall to storage ratio cannot be determined from soil properties alone. Very little is currently known about the spatial structure of the critical zone and its rock moisture storage capacity, and yet it is crucial to anticipating the threats of drought.

* What opportunities for training and professional development has the project provided?

In the ER CZO post-docs, graduate students and undergraduate typically work with several of our PIs whose expertise range across atmospheric science, tree physiology, geomorphology, microbial ecology, geobiology, hydrology, stream ecology and geochemistry. Geologists and atmospheric scientists work on where trees get their water, microbial ecologists study hydrologic processes and geochemistry, and stream ecologists explore the geomorphic processes that control fish distribution and foodwebs. Students freely interact across four departments, four deans and three colleges. This training will create “critical zone scientists.”

During monthly meetings attended by ER CZO participants, both undergraduate and graduate students present their research and debate findings. These presentations fine tune their speaking skills and sharpen their research efforts. We discuss research findings, future plans and ways to connect the pieces of the critical zone. We subsidize students to attend meetings and work closely with them to prepare them for presentations and to advise them on manuscript preparation. Additionally, many of the CZO graduate students have supervised multiple undergraduates, both in the field and in the laboratory.

The graduate students have formed a group identity and regularly share technology and field skills. Students frequently train new students on deployment, operation and data collection from field instruments. Students engage with the public through invited talks, outreach activities, and collaborations with non-profits and government organizations. The PIs also spend considerable time in the field with graduate students, training them in field methods and developing measurement procedures, and in the laboratory to teach analytical and modeling methods.

* How have the results been disseminated to communities of interest?

Our CZOMP lists our strategy for engagement with other CZOs – which focused on common questions and measurements and cross-site research. We proposed that several strategies to engage the larger community including publishing papers, presenting findings at meetings, sharing data, and welcoming participation by groups not affiliated with the CZO network.

Researchers in the CZO regularly present their findings at conferences, meetings, invited talks, and seminars. In the past year, graduate students, postdocs, and PI's have presented at: the 2018 American Geophysical Union Meeting (J. Hahm, J. Oshun), the 2019 Salmonid Restoration Foundation meeting (G. Rossi, D. Dralle), the 2019 Eel River Forum Foundation Meeting (P. Georgakakos, M. Power), the Center for Watershed Sciences at UC Davis (P. Georgakakos) the Water, Climate, and Environment Seminar at UT Austin (A. Tune), the Botany Lunch Seminar at UC Berkeley (K. Crutchfield-Peters), Geological Society of America 2018, (Druhan, Wang, Rempe and others), Soil Science Society of America 2018 (Druhan, Wang, Rempe and others), and Princeton University (Druhan).

Engagement by the research community is extensive and continues to grow (individuals from over 27 institutions). In the past year we have collaborated with University of California, Davis (M. Miller) to conduct genetic analyses on *O. mykiss*, Babson College (N. Karst) on methods of stream flow time series analysis, University of Illinois (J. Druhan) and University of Texas, Austin (D. Rempe on hydrologic processes, solute evolution, and reactive transport modeling through the critical zone and P. Bennett on microbial biogeochemistry), University of Minnesota (X. Feng) on calibrating a sap flow model, the Senckenberg Institute (T. Hickler) on implementing rock moisture in dynamic global vegetation models, UC Merced (A. Berhe, F. Santos) on soil carbon dynamics Universite de Rennes (M. Bormans) on cyanobacterial flotation, University of California, Santa Cruz (R. Kudela) on cyanobacterial toxicity, the California Dept. of Fish and Wildlife (A. Renger, S. Gallagher, M. Knechtle) on pacific salmon populations, Wright State University (Y. Vadeboncoeur) on algal blooms, Colorado State University (C. Myrick) and Michigan State (J. Breck) on fish thermal refugia, Lawrence Livermore National Laboratory (A. Visser) on water tracing using radioisotopes, Notre Dame University (M. Muller) on hydrologic stochastic modeling, University of California, Berkeley on evapotranspirative modeling (D. Baldocchi, Y. Ryu), freshwater food webs (T. Grantham), and algal food webs (J. Marks, B. Hungate, J. Brashares, M. Polson, E. Biber), the California Sea Grant Salmon and Steelhead Monitoring Program in the Russian River, the Gold Ridge Research Conservation District, the Cawthron Institute in New Zealand (S. Wood) on cyanobacteria, Bowling Green State University (G. Bullerjahn, T. Davis) to study and sample benthic cyanobacteria in California and Ohio. We collaborated with University of California Davis (J. Medellin-Azuara), California State University San Marcos (R. Hristova), University of Wisconsin (R. Lowe), St. Catherine University (P. Furey), University of Minnesota (J. Finlay), University of North Carolina Greenville (M. Tsui) on algal food webs, University of Arkansas (J. Marshall) to document wind-induced forces by trees through their roots on underlying bedrock, Penn State University (S. Brantley and X. Gu) on porosity generation in the critical zone, and Rutgers University (Y. Fan) on the role of the deep critical zone in climate processes.

* What do you plan to do during the next reporting period to accomplish the goals?

As specified in the CZO reporting guidelines our goals are presented as a graphical timeline. See attached.

Supporting Files

Filename	Description	Uploaded By	Uploaded On
Question 1 attachment.pdf	Question 1 Activities Supplement	William Dietrich	10/18/2019
Graphical Timeline 2019_wed.pdf	Graphical Timeline- Goals for next reporting period	William Dietrich	10/18/2019
Special Reporting Requirements 2019-2020.pdf	CZO Special Reporting Requirements 2019	William Dietrich	10/18/2019

Products

Books

Book Chapters

Inventions

Journals or Juried Conference Papers

Baldocchi, D., Dralle, D.N., Jiang, C. & Ryu, Y. (2019). How Much Water is Evaporated Across California? A Multi-Year Assessment Using a Biophysical Model Forced with Satellite Remote Sensing Data. *Water Resources Research*. 55 (4), 2722. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: <https://doi.org/10.1029/2018WR023884>

Baldocchi, D.D., Dralle, D.N, Jiang, C., & Ryu, Y. (2017). How Much Water is Evaporated Across California? A Multi-Year Assessment Using a Biophysical Model Forced with Satellite Remote Sensing Data. . *Agricultural and Forest Meteorology*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Bouma-Gregson, K., Olm, M.R., Probst, A.J., Anantharaman, K., Power, M.E. & J.F. Banfield. (2019). Impacts of microbial assemblage and environmental conditions on the distribution of anatoxin-a producing cyanobacteria within a river network.. *The International Society of Microbial Ecology Journal*. 13 1618. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: <https://doi.org/10.1038/s41396-019-0374-3>

Bouma-Gregson, K., Olm, M.R., Probst, A.J., Anantharaman, K., Power, M.E., Banfield, J.F. (2018). Microbial diversity and metabolic potential in cyanotoxin producing cyanobacterial mats throughout a river network.. *ISME journal*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: <https://doi.org/10.1101/294421>

Callahan, R.P., Dosseto, A., Ferrier, K. L., Dixon, J. C., Hahm, W. J., Jessup, B. S, Miller, S. N., Sklar, L. S., & Riebe, C. S. (2018). Lithologic and topographic control of landscape evolution in the southern Sierra Nevada, California.. *Geological Society of America*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

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Fan, Y., Clark, M., Lawrence, D. M., Swenson, S., Band, L. E., Brantley, S. L., P. D. Brooks, W. E. Dietrich, A. Flores, G. Grant, J. W. Kirchner, D. S. Mackay, J. J. McDonnell, P. C. D. Milly, P. L. Sullivan, C. Tague, H. Ajami, N. Chaney, A. Hartmann, P. Hazenberg, J. McNamara, J. Pelletier, J. Perket, E. Rouholahnejad-Freund, T. Wagener, X. Zeng, E. Beighley, J. Buzan, M. Huang, B. Livneh, B. P. Mohanty, B. Nijssen, M. Safeeq, C. Shen, W. van Verseveld, J. Volk & D. Yamazaki. (2019). Hillslope hydrology in global change research and Earth system modeling.. *Water Resources Research*. 55 (2), 1737. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: <https://doi.org/10.1029/2018WR023903>

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Hahm, W.J., Dietrich, W.E., Rempe, D.N., Dralle, D.N., Dawson, T.E., Lovill, S., Bryk, A.B., Bish, D., & Schieber, J. (2018). Lithologically controlled bedrock weathering determines water storage capacity and presence of evergreen forest versus savanna under similar climate.. *Water Resources Research*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Hahm, W.J., Dralle, D.N., Rempe, D.M., Bryk, A.B., Thompson, S.E., Dawson, T.E. & W.E. Dietrich. (2019). Low Subsurface Water Storage Capacity Relative to Annual Rainfall Decouples Mediterranean Plant Productivity and Water Use From Rainfall Variability.. *Geophysical Research Letters*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: <https://doi.org/10.1029/2019GL083294>

Hahm, W.J., Rempe, D.R., Dralle, D.N., Dawson, T., Lovill, S., Bryk, A., Bish, D., Schieber, J. & W.E. Dietrich. (2019). Lithologically controlled subsurface critical zone thickness and water storage capacity determine regional plant community composition. *Water Resources Research*. 55 (4), 3028. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: <https://doi.org/10.1029/2018WR023760>

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Karst, N.J., Dralle, D.N., & Muller, M. (2018). Capturing inter-annual stream flow variability to improve annual flow duration curves. *Water Resources Research*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Kelson, S.J. & Carlson, S.M. (2019). Do precipitation extremes drive growth and migration timing of a Pacific salmonid fish in Mediterranean-climate streams?. *Ecosphere*. 10 (3), e02618. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: <https://doi.org/10.1002/ecs2.2618>

Kelson, S.J., Miller, M.R., Thompson, T.Q., O'Rourke, S.M. & Carlson S.M. (2019). Do genomics and sex predict migration in a partially migratory salmonid fish, *Oncorhynchus mykiss*?. *Canadian Journal of Fisheries and Aquatic Sciences*.. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: <https://doi.org/10.1139/cjfas-2018-0394>

Lovill, S., Hahm, W. J., & Dietrich, W. E. (2018). Drainage from the critical zone: lithologic controls on the persistence and spatial extent of wetted channels during the summer dry season.. *Water Resources Research*. 54 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: <https://doi.org/10.1029/2017WR021903>

Sculley, J.B., Lowe, R.L., Nittrouer, C.A., Drexler, T.M. & Power, M.E. (2017). Eighty years of food-web response to interannual variation in discharge recorded in river diatom frustules from an ocean sediment core. *PNAS*. . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: <https://doi.org/10.1073/pnas.1611884114>

Licenses

Other Conference Presentations / Papers

Vrettas, M (2014). *A stochastic hydraulic conductivity model for weathered bedrock*. Math and Climate Research Network Annual Meeting. Chapel Hill, NC. Status = OTHER; Acknowledgement of Federal Support = Yes

Dietrich, W.E Rempe, D. M (2014). *Critical zone evolution legacy: what happened matters to what happens*. CUAHSI Fourth Biennial Symposium on Water Science and Engineering.. Shepardstown, WV. Status = OTHER; Acknowledgement of Federal Support = Yes

Keith Bouma-Gregson (2017). *Cyanobacteria and Citizens in the Eel River, Northern California*. EPA Region 9 HABS Meeting. Costa Mesa, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Mary Power (2017). *Deepening our sense of place*. Organismal Biology, Ecology & Evolution Seminar Series, University of Montana. Missoula, MT. Status = OTHER; Acknowledgement of Federal Support = Yes

Mary Power (2017). *Deepening our sense of place*. Earth Month at Oklahoma U Distinguished Speaker Series. Norman, OK. Status = OTHER; Acknowledgement of Federal Support = Yes

Stephanie Carlson (2016). *Eco-Evolutionary Dynamics in Pacific Salmon and Trout*. Centre for Ecological and Evolutionary Synthesis, University of Oslo. Norway. Status = OTHER; Acknowledgement of Federal Support = Yes

Carlson, S.M. (2016). *Eco-evolutionary dynamics in Pacific salmon and trout*. Department of Ecology Seminar, University of Barcelona. Barcelona, Spain. Status = OTHER; Acknowledgement of Federal Support = Yes

Carlson, S.M. (2016). *Eco-evolutionary dynamics in Pacific salmon and trout*. Department of Environmental Science, University of Girona, Spain. Girona, Spain. Status = OTHER; Acknowledgement of Federal Support = Yes

Carlson, S.M. (2016). *Eco-evolutionary dynamics in Pacific salmon and trout*. INRA Seminar. Sant-Pee-Sur-Nivelle, France. Status = OTHER; Acknowledgement of Federal Support = Yes

Carlson, S.M. (2016). *Eco-evolutionary dynamics in Pacific salmon and trout*. Centre for Ecological and Evolutionary Synthesis (CEES) Seminar, University of Oslo. Oslo, Norway. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Carlson, S.M. (2016). *Eco-evolutionary dynamics in Pacific salmon and trout*. Department of Ecology, University of Toulouse.. Toulouse, France. Status = OTHER; Acknowledgement of Federal Support = Yes

Stephanie Carlson (2017). *Eco-evolutionary dynamics of Pacific salmon and trout*. Southern Illinois University, Zoology Seminar Series. Carbondale, IL. Status = OTHER; Acknowledgement of Federal Support = Yes

W. Jesse Hahm (2016). *Ecohydrological Consequences of Critical Zone Structure in the Franciscan Formation, Northern California Coast Ranges*. AGU Fall Meeting. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Starr, E., Firestone, MK., Banfield, J. (2015). *Eel River Soil Microbial Ecology Update*. CZO Microbial Ecology Workshop, Argonne National Lab. Lemont, IL. Status = OTHER; Acknowledgement of Federal Support = Yes

Schaaf, C (2015). *Environmental factors in trematode parasite dynamics: water temperature, snail density and black spot disease parasitism in California steelhead (Oncorhynchus mykiss)*. Spring 2015 Environmental Sciences Symposium. Berkeley, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Kelson, S., Carlson, SM. (2016). *Evolution and Ecology of Partial Migration in a Pacific Salmonid*. Mildred Mathias Symposium. Bodega Bay, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Kelson, S., Carlson, SM. (2016). *Evolution and Ecology of a Partially Migratory Fish*. UC Berkeley Wildlife Conservation Seminar. Berkeley, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Suzanne Kelson (2016). *Evolution and ecology of partial migration in a salmonid fish (Oncorhynchus mykiss)*. California Chapter of Society of Freshwater Sciences. Davis, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

- Stephanie Carlson (2016). *Evolutionary Ecology and Conservation of Freshwater Fishes*. Cambridge University, Department of Zoology, Behaviour, Ecology, and Evolution Series. Cambridge, UK. Status = OTHER; Acknowledgement of Federal Support = Yes
- Stephanie Carlson (2016). *Evolutionary Ecology and Conservation of Freshwater Fishes*. University of Lisbon, Center for Ecology, Evolution, and Environmental Change. Lisbon, Portugal. Status = OTHER; Acknowledgement of Federal Support = Yes
- Stephanie Carlson (2017). *Evolutionary ecology and conservation of freshwater fishes*. University of Washington, School of Aquatic and Fishery Sciences. Seattle, WA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Mary Power (2016). *Floods, Droughts, and Food Chains*. HHMI Holiday Lectures. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Mary Power (2016). *Floods, drought, and the length of chains in algal-based river food webs*. Graduate Student invited Seminar, University of Arkansas. Fayetteville, AK. Status = OTHER; Acknowledgement of Federal Support = Yes
- Phil Georgakakos (2017). *Interannual variability in of Sacramento Pikeminnow movements into the upper South Fork Eel River*. Cal-Neva AFS annual conference. Eureka, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Phil Georgakakos (2017). *Interannual variability in of Sacramento Pikeminnow movements into the upper South Fork Eel River*. ESA Annual Conference. Portland, OR. Status = OTHER; Acknowledgement of Federal Support = Yes
- Dietrich, W.E. (2014). *Linking Weathering, Rock Moisture Dynamics, Geochemistry, Runoff, Vegetation and Atmospheric Processes through the Critical Zone: Graduate Student led Research at the Eel River Critical Zone Observatory*. American Geophysical Union 2014 Fall Meetin. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Gabe Rossi (2017). *Mapping Steelhead Behavior -Implications for Water Management*. Cal-Neva AFS Conference. Eureka, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Mary Power (2017). *Pattern, process and science-informed policy*. University of California, Santa Cruz Departmental Seminar. Santa Cruz, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Fung, Inez (2015). *Plants Water Climate - Assessing the Climatic Impacts of Afforestation*. Johns Hopkins - Dept of Earth Science. Baltimore, MD. Status = OTHER; Acknowledgement of Federal Support = Yes
- Fung, I (2015). *Plants, Water and Climate*. Mills College Women in Science Lecture Series. Oakland, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Fung, I (2015). *Plants, Water and Climate*. MIT Earth and Planetary Science Department Lecture Series. Cambridge, MA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Jill Marshall (2016). *Quantifying the role of trees as Critical Zone architects employing crowbars, wedges and other tools of soil production*. AGU Fall Meeting. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Suzanne Kelson (2017). *Small Waterfall Barriers Can Alter the Frequency of Resident Versus Migratory O. mykiss in Headwater Streams*. California-Nevada Chapter of American Fisheries Society. Eureka, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Dietrich, W.D. (2016). *The Critical Zone in Hilly and Mountainous Landscapes*. The 3rd International Conference on Hydrogeology. Beijing, China. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Rempe, D. (2016). *The Ecological Significance of Landscape-scale Weathering Patterns And Rock Moisture: Observations from the Eel River Critical Zone Observatory in Northern California*. Department of Earth, Atmospheric, and Planetary Sciences Colloquia. Lafayette, IN. Status = OTHER; Acknowledgement of Federal Support = Yes
- Kelson, S., Carlson, SM. (2016). *The Influence of Natural Barriers on the Distribution of Steelhead and Rainbow Trout in Tributaries of the South Fork Eel River*. Salmonid Restoration Federation Conference. Fortuna, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Kelson, S, Carlson, SM (2015). *The Influence of Waterfalls and Hydrology on the Spatial Zonation of O. mykiss*. Pacific States Marine Fisheries Commission Steelhead Managers Meeting. Asilomar, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Dietrich, W.E. (2014). *The US Critical Zone Observatory program*. Frontiers in International Critical Zone Science. Beijing, China. Status = OTHER; Acknowledgement of Federal Support = Yes

Dietrich, W.E. (2014). *The soil is not enough: going inside hillslopes to understand moisture return to the atmosphere, and controls on tree distribution, stream ecosystems, and landscape evolution*. Invited talk, Department of Earth, Atmospheric and Planetary Sciences, MIT. Cambridge, MA. Status = OTHER; Acknowledgement of Federal Support = Yes

Dietrich, W.E. (2015). *The soil is not enough: going inside hillslopes to understand moisture return to the atmosphere, and controls on tree distribution, stream ecosystems, and landscape evolution*. Invited talk, Department of Geography, Simon Fraser University. Burnaby, BC, Canada. Status = OTHER; Acknowledgement of Federal Support = Yes

Mary Power (2016). *The state of the natural ecosystem: The Water- Landscape-Fire nexus*. Lake Tahoe summit on Aquatic Ecosystems in the Western US under Climate Change. Lake Tahoe, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Keith Bouma-Gregson (2016). *Tipping towards toxicity: effects of benthic cyanobacteria on food webs and water quality in a California river network*. New Zealand Societies for Freshwater Science. Invercargill, New Zealand. Status = OTHER; Acknowledgement of Federal Support = Yes

Mary Power (2016). *Trophic Cascades in Rivers*. HHMI Holiday Lectures. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Spencer Diamond (2017). *Uncovering Context and Dynamics of Climate Relevant Biogeochemical Functions in Soil by Linking Microbial Genomes to Functional Genes with Multi-'Omic' Analysis*. ASM Microbe. New Orleans, LA. Status = OTHER; Acknowledgement of Federal Support = Yes

Fung, Inez (2016). *Water in Motion*. Harvard EPS Seminar Series. Cambridge, MA. Status = OTHER; Acknowledgement of Federal Support = Yes

Fung, Inez (2015). *Water in Motion*. Chinese Academy of Sciences - Institute of Earth Environment. Xian China. Status = OTHER; Acknowledgement of Federal Support = Yes

Inez Fung (2016). *Water in Motion: Mysteries from Northern California*. Caltech. Pasadena, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

Mary Power (2017). *Water usage in Oklahoma: How should we share a precious resource?*. Earth Month at OU Distinguished Speaker Series. Norman, OK. Status = OTHER; Acknowledgement of Federal Support = Yes

Other Products

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

Allison Sharrar. *Bacterial secondary metabolite biosynthetic potential in soil varies with phylum, depth, and vegetation type*. (2019). University of California, Berkeley. Acknowledgement of Federal Support = Yes

William Jesse Hahm. *Critical Zone Ecohydrology of the Northern California Coast Ranges*. (2019). University of California, Berkeley. Acknowledgement of Federal Support = Yes

Jia Wang. *Linkages between fluid flow paths, reactive gases and chemical weathering across a shale bedrock hillslope*. (2019). University of Illinois Urbana Champaign. Acknowledgement of Federal Support = Yes

Keith Bouma-Gregson. *The Ecology of Benthic Toxicogenic Anabaena and Phormidium (Cyanobacteria) in the Eel River, California*. (2017). UC Berkeley. Acknowledgement of Federal Support = Yes

Websites

Participants/Organizations

Research Experience for Undergraduates (REU) funding

Form of REU funding support: REU supplement

How many REU applications were received during this reporting period? Nothing to Report

How many REU applicants were selected and agreed to participate during this reporting period? Nothing to Report

REU Comments: No REU in 2018-2019

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Dietrich, William	PD/PI	1
Bishop, James	Co PD/PI	0
Carlson, Stephanie	Co PD/PI	1
Power, Mary	Co PD/PI	1
Thompson, Sally	Co PD/PI	0
Banfield, Jillian	Faculty	1
Dawson, Todd	Faculty	6
Firestone, Mary	Faculty	0
Fung, Inez	Faculty	6
Marshall, Jill	Faculty	1
Bouma-Gregson, Keith	Postdoctoral (scholar, fellow or other postdoctoral position)	0
Chung, Michaella	Postdoctoral (scholar, fellow or other postdoctoral position)	0
Dralle, David	Postdoctoral (scholar, fellow or other postdoctoral position)	10
Vaughn, Lydia	Postdoctoral (scholar, fellow or other postdoctoral position)	12

Name	Most Senior Project Role	Nearest Person Month Worked
John, Smith	Other Professional	6
Roy, Sarah	Other Professional	12
Baxter, Wendy	Technician	6
Bode, Collin	Technician	6
Minton, Brandon	Technician	0
Rieth, Gunnar	Technician	6
Speiser, William	Technician	6
Wolf, Marshall	Technician	0
Bilir, T.	Graduate Student (research assistant)	6
Crutchfield-Peters, Kelsey	Graduate Student (research assistant)	6
Georgakakos, Philip	Graduate Student (research assistant)	6
Greer, George	Graduate Student (research assistant)	6
Hahm, William	Graduate Student (research assistant)	6
Kelson, Suzanne	Graduate Student (research assistant)	2
Lee, Shawn	Graduate Student (research assistant)	6
Rossi, Gabe	Graduate Student (research assistant)	6
Schmidt, Logan	Graduate Student (research assistant)	6
Sharrar, Allison	Graduate Student (research assistant)	6
Starr, Evan	Graduate Student (research assistant)	0
Tune, Alison	Graduate Student (research assistant)	6
Wang, Jia	Graduate Student (research assistant)	2
Nelson, Mariel	Non-Student Research Assistant	12
Pneh, Shelley	Non-Student Research Assistant	2
Bolas, Theodore	Undergraduate Student	0

Name	Most Senior Project Role	Nearest Person Month Worked
Boslough, Kobrina	Undergraduate Student	3
Carey, Alex	Undergraduate Student	3
Flynn, Keanne	Undergraduate Student	3
Jamison, Hunter	Undergraduate Student	3
Johannson, Hannah	Undergraduate Student	3
Jougla, Jac	Undergraduate Student	3
Kelkar, Saumitra	Undergraduate Student	3
LaPaglia, Nick	Undergraduate Student	0
Larkin, Samuel	Undergraduate Student	3
Malone, Kelly	Undergraduate Student	3
McKillop-Herr, Shannon	Undergraduate Student	3
Richmond, Keana	Undergraduate Student	0
Sanders, Maryn	Undergraduate Student	3
Schaaf, Cody	Undergraduate Student	0
Schadlich, Daisy	Undergraduate Student	0
Schugel, Cain	Undergraduate Student	0
Setlur, Neeraja	Undergraduate Student	0
Shekelle, Kristen	Undergraduate Student	0
Slaughter, Weston	Undergraduate Student	0
Spankowski, Robert	Undergraduate Student	0
Uva, Victoria	Undergraduate Student	0
Young, Candice	Undergraduate Student	0
Yu, Katelyn	Undergraduate Student	0

Full details of individuals who have worked on the project:

William E Dietrich**Email:** bill@eps.berkeley.edu**Most Senior Project Role:** PD/PI**Nearest Person Month Worked:** 1**Contribution to the Project:** Lead Investigator, provided guidance on project's objectives; assisted in implementing research questions.**Funding Support:** EAR-1360760**International Collaboration:** No**International Travel:** No**James K Bishop****Email:** jkbishop@berkeley.edu**Most Senior Project Role:** Co PD/PI**Nearest Person Month Worked:** 0**Contribution to the Project:** Investigator**Funding Support:** None**International Collaboration:** No**International Travel:** No**Stephanie M Carlson****Email:** smcarlson@berkeley.edu**Most Senior Project Role:** Co PD/PI**Nearest Person Month Worked:** 1**Contribution to the Project:** Provided guidance on project's objectives; assisted in implementing research questions.**Funding Support:** none**International Collaboration:** No**International Travel:** No**Mary E Power****Email:** mepower@berkeley.edu**Most Senior Project Role:** Co PD/PI**Nearest Person Month Worked:** 1**Contribution to the Project:** Provided guidance on project's objectives; assisted in implementing research questions.**Funding Support:** NSF award 1656009**International Collaboration:** No**International Travel:** No**Sally Thompson****Email:** sally.thompson@berkeley.edu**Most Senior Project Role:** Co PD/PI**Nearest Person Month Worked:** 0**Contribution to the Project:** Investigator

Funding Support: none

International Collaboration: No

International Travel: No

Jillian Banfield

Email: jbanfield@berkeley.edu

Most Senior Project Role: Faculty

Nearest Person Month Worked: 1

Contribution to the Project: Provided guidance on project's objectives; assisted in implementing research questions.

Funding Support: NSF award 1656009, Spatial and environmental barriers to gene flow driving cyanobacterial biogeography in a river network

International Collaboration: No

International Travel: No

Todd Dawson

Email: tdawson@berkeley.edu

Most Senior Project Role: Faculty

Nearest Person Month Worked: 6

Contribution to the Project: Provided guidance on project's objectives; assisted in implementing research questions.

Funding Support: None

International Collaboration: No

International Travel: No

Mary Firestone

Email: mkfstone@berkeley.edu

Most Senior Project Role: Faculty

Nearest Person Month Worked: 0

Contribution to the Project: Provided guidance on project's objectives; assisted in implementing research questions.

Funding Support: none

International Collaboration: No

International Travel: No

Inez Fung

Email: ifung@berkeley.edu

Most Senior Project Role: Faculty

Nearest Person Month Worked: 6

Contribution to the Project: Provided guidance on project's objectives; assisted in implementing research questions.

Funding Support: None

International Collaboration: No

International Travel: No

Jill Marshall

Email: jillm@uark.edu

Most Senior Project Role: Faculty

Nearest Person Month Worked: 1

Contribution to the Project: Investigating wind-induced forces by trees through their roots on underlying bedrock

Funding Support: University of Arkansas

International Collaboration: No

International Travel: No

Keith Bouma-Gregson

Email: kbg@berkeley.edu

Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)

Nearest Person Month Worked: 0

Contribution to the Project: Task 4- Field work, assisted in implementing research questions; performed data collection, sampling and analysis.

Funding Support: NSF award 1656009, SG: Spatial and environmental barriers to gene flow driving cyanobacterial biogeography in a river network

International Collaboration: No

International Travel: No

Michaella Chung

Email: michaellachung@berkeley.edu

Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)

Nearest Person Month Worked: 0

Contribution to the Project: Using UAVs to collect water samples

Funding Support: None

International Collaboration: No

International Travel: No

David Dralle

Email: daviddralle@gmail.com

Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)

Nearest Person Month Worked: 10

Contribution to the Project: Assisted in implementing research questions; performed data collection, sampling and analysis. Now working as a postdoc modeling components of the AWESOM model.

Funding Support: NSF Graduate Research Fellowship

International Collaboration: No

International Travel: No

Lydia Vaughn

Email: lydiajsvaughn@gmail.com

Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)

Nearest Person Month Worked: 12

Contribution to the Project: Conducting research in soil carbon turnover rates, decomposition processes, and their biogeochemical controls.

Funding Support: none

International Collaboration: No

International Travel: No

Smith Scott John

Email: jscottsf@berkeley.edu

Most Senior Project Role: Other Professional

Nearest Person Month Worked: 6

Contribution to the Project: Helped design and implement new sensor database

Funding Support: UC Natural Reserve System

International Collaboration: No

International Travel: No

Sarah Roy

Email: smroy@berkeley.edu

Most Senior Project Role: Other Professional

Nearest Person Month Worked: 12

Contribution to the Project: Oversees the general administrative functions of the CZO, including financial operations, grants management, and facilities operations, as well as overall technical management of the research, with the authority to organize, coordinate, and monitor projects to meet milestones and goals.

Funding Support: University of California Berkeley VCRO and Dean

International Collaboration: No

International Travel: No

Wendy Baxter

Email: wendy.l.baxter@berkeley.edu

Most Senior Project Role: Technician

Nearest Person Month Worked: 6

Contribution to the Project: Implementation and maintenance of CZO sampling infrastructure.

Funding Support: UC Natural Reserve System

International Collaboration: No

International Travel: No

Collin Bode

Email: collin@berkeley.edu

Most Senior Project Role: Technician

Nearest Person Month Worked: 6

Contribution to the Project: As Data Manager, Mr. Bode maintains the wireless network, operates and maintains the sensor observatories, develops and maintains the sensor observatory database and website for archiving and disseminating data, and performs spatial analysis of the LiDAR flown at the Angelo Coast Range Reserve and extended areas.

Funding Support: University of California Berkeley VCRO and Dean

International Collaboration: No

International Travel: No

Brandon Minton

Email: BrandonMinton@austin.utexas.edu

Most Senior Project Role: Technician

Nearest Person Month Worked: 0

Contribution to the Project: Developed and implemented gas sampling and monitoring system. Collected and analyzed vadose zone gas samples. Deployed geophysical instrumentation for monitoring rock moisture.

Funding Support: Department of Geological Sciences, University of Texas at Austin

International Collaboration: No

International Travel: No

Gunnar Rieth

Email: grieth@berkeley.edu

Most Senior Project Role: Technician

Nearest Person Month Worked: 6

Contribution to the Project: Led VMS sampling campaigns

Funding Support: none

International Collaboration: No

International Travel: No

William Speiser

Email: williamhspeiser@berkeley.edu

Most Senior Project Role: Technician

Nearest Person Month Worked: 6

Contribution to the Project: Led VMS sampling campaigns

Funding Support: None

International Collaboration: No

International Travel: No

Marshall Wolf

Email: marshallwolf@berkeley.edu

Most Senior Project Role: Technician

Nearest Person Month Worked: 0

Contribution to the Project: Led VMS sampling campaigns

Funding Support: None

International Collaboration: No

International Travel: No

T. Eren Bilir

Email: tebilir@gmail.com

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Conducted research with stem psychrometers, conducting drone experiment

Funding Support: None

International Collaboration: No

International Travel: No

Kelsey Crutchfield-Peters

Email: kcrutchfieldpeters@berkeley.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Task 3- Field work; performed data collection, sampling and analysis.

Funding Support: NSF Graduate Research Fellowship

International Collaboration: No

International Travel: No

Philip Georgakakos

Email: pgeorgakakos@berkeley.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Task 4- Field work; performed data collection, sampling and analysis.

Funding Support: UC Berkeley ISEECI graduate award

International Collaboration: No

International Travel: No

George Greer

Email: georgegreer@berkeley.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Task 4- Field work; performed data collection, sampling and analysis.

Funding Support: None

International Collaboration: No

International Travel: No

William Jesse Hahm

Email: wjhahm@berkeley.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Task 1- Field work; performed data collection, sampling and analysis.

Funding Support: None

International Collaboration: No
International Travel: No

Suzanne Kelson

Email: skelson@berkeley.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 2

Contribution to the Project: Task 4- Field work; performed data collection, sampling and analysis.

Funding Support: NSF Graduate Research Fellowship

International Collaboration: No

International Travel: No

Shawn Lee

Email: shawnlee@berkeley.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Analyzed geophysical data collected at ERCZO

Funding Support: Jackson School Fellowship, Department of Geological Sciences, University of Texas at Austin

International Collaboration: No

International Travel: No

Gabe Rossi

Email: rossfactor@berkeley.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Task 4- Studying stream ecology

Funding Support: UC Berkeley ISEECI graduate award

International Collaboration: No

International Travel: No

Logan Schmidt

Email: loganmschmidt@utexas.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Monitoring rock moisture using novel geophysical techniques

Funding Support: Department of Geological Sciences, University of Texas at Austin

International Collaboration: No

International Travel: No

Allison Sharrar

Email: asharrar@berkeley.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Task 2- Field work; performed data collection, sampling and analysis.

Funding Support: None

International Collaboration: No

International Travel: No

Evan Starr

Email: evan.starr@berkeley.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 0

Contribution to the Project: Task 2- Field work; performed data collection, sampling and analysis.

Funding Support: none

International Collaboration: No

International Travel: No

Alison Tune

Email: alisontune@utexas.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 6

Contribution to the Project: Leading characterization of dissolved organic and inorganic carbon and carbon isotope characterization of vadose zone fluids

Funding Support: Department of Geological Sciences, University of Texas at Austin

International Collaboration: No

International Travel: No

Jia Wang

Email: Jiawang2@illinois.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 2

Contribution to the Project: Anion analysis

Funding Support: University of Illinois Urbana-Champaign

International Collaboration: No

International Travel: No

Mariel Nelson

Email: marielnelson@berkeley.edu

Most Senior Project Role: Non-Student Research Assistant

Nearest Person Month Worked: 12

Contribution to the Project: Data collection, organization, and analysis

Funding Support: none

International Collaboration: No

International Travel: No

Shelley Pneh**Email:** shelleypneh@berkeley.edu**Most Senior Project Role:** Non-Student Research Assistant**Nearest Person Month Worked:** 2**Contribution to the Project:** Assisted in collection and accession of riverine invertebrate communities**Funding Support:** None**International Collaboration:** No**International Travel:** No**Theodore Bolas****Email:** bolas@berkeley.edu**Most Senior Project Role:** Undergraduate Student**Nearest Person Month Worked:** 0**Contribution to the Project:** Assisted graduate students collecting data**Funding Support:** None**International Collaboration:** No**International Travel:** No**Kobrina Boslough****Email:** boslough@berkeley.edu**Most Senior Project Role:** Undergraduate Student**Nearest Person Month Worked:** 3**Contribution to the Project:** Assisted graduate students collecting data**Funding Support:** None**International Collaboration:** No**International Travel:** No**Alex Carey****Email:** alexjeancarey@berkeley.edu**Most Senior Project Role:** Undergraduate Student**Nearest Person Month Worked:** 3**Contribution to the Project:** Assisted graduate students collecting data**Funding Support:** none**International Collaboration:** No**International Travel:** No**Keanne Flynn****Email:** kmflynn24@berkeley.edu**Most Senior Project Role:** Undergraduate Student**Nearest Person Month Worked:** 3**Contribution to the Project:** Assisted graduate students collecting data**Funding Support:** None

International Collaboration: No

International Travel: No

Hunter Jamison

Email: hjamison@berkeley.edu

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 3

Contribution to the Project: Assisted graduate students collecting data

Funding Support: none

International Collaboration: No

International Travel: No

Hannah Johannson

Email: hannahjohannson@berkeley.edu

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 3

Contribution to the Project: Assisted graduate students collecting data

Funding Support: none

International Collaboration: No

International Travel: No

Jac Jougla

Email: jac.jougla@gmail.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 3

Contribution to the Project: Assisted graduate students collecting data

Funding Support: none

International Collaboration: No

International Travel: No

Saumitra Kelkar

Email: saumitra_kelkar@berkeley.edu

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 3

Contribution to the Project: Assisted graduate students collecting data

Funding Support: none

International Collaboration: No

International Travel: No

Nick LaPaglia

Email: nalapaglia@berkeley.edu

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 0

Contribution to the Project: Assisted graduate students collecting data

Funding Support: None

International Collaboration: No

International Travel: No

Samuel Larkin

Email: sam.larkin504@berkeley.edu

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 3

Contribution to the Project: Assisted graduate students collecting data

Funding Support: none

International Collaboration: No

International Travel: No

Kelly Malone

Email: kamalone@utexas.edu

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 3

Contribution to the Project: Assisted graduate students collecting data

Funding Support: Department of Geological Sciences, University of Texas at Austin

International Collaboration: No

International Travel: No

Shannon McKillop-Herr

Email: smckillopherr@berkeley.edu

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 3

Contribution to the Project: Assisted graduate students collecting data

Funding Support: none

International Collaboration: No

International Travel: No

Keana Richmond

Email: krichmond@berkeley.edu

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 0

Contribution to the Project: Assisted graduate students collecting data

Funding Support: None

International Collaboration: No

International Travel: No

Maryn Sanders**Email:** marynsanders@berkeley.edu**Most Senior Project Role:** Undergraduate Student**Nearest Person Month Worked:** 3**Contribution to the Project:** Assisted graduate students collecting data**Funding Support:** none**International Collaboration:** No**International Travel:** No**Cody Schaaf****Email:** codyschaaf@berkeley.edu**Most Senior Project Role:** Undergraduate Student**Nearest Person Month Worked:** 0**Contribution to the Project:** Assisted in analysis of fish disease occurrence**Funding Support:** None**International Collaboration:** No**International Travel:** No**Daisy Schadlich****Email:** dschadlich@berkeley.edu**Most Senior Project Role:** Undergraduate Student**Nearest Person Month Worked:** 0**Contribution to the Project:** Assisted graduate students with data collection**Funding Support:** none**International Collaboration:** No**International Travel:** No**Cain Schugel****Email:** cainschugel@berkeley.edu**Most Senior Project Role:** Undergraduate Student**Nearest Person Month Worked:** 0**Contribution to the Project:** Assisted graduate students collecting data**Funding Support:** None**International Collaboration:** No**International Travel:** No**Neeraja Setlur****Email:** rempe@jsg.utexas.edu**Most Senior Project Role:** Undergraduate Student**Nearest Person Month Worked:** 0**Contribution to the Project:** Assisted graduate students collecting data**Funding Support:** Department of Geological Sciences, University of Texas at Austin

International Collaboration: No
International Travel: No

Kristen Shekelle

Email: kshekelle@berkeley.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 0

Contribution to the Project: Assisted graduate students collecting data

Funding Support: None

International Collaboration: No
International Travel: No

Weston Slaughter

Email: wslaughter@berkeley.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 0

Contribution to the Project: Assisted graduate students collecting data

Funding Support: None

International Collaboration: No
International Travel: No

Robert Spankowski

Email: robert.spankowski@berkeley.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 0

Contribution to the Project: Assisted graduate students collecting data

Funding Support: None

International Collaboration: No
International Travel: No

Victoria Uva

Email: vuva@berkeley.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 0

Contribution to the Project: Assisted graduate students collecting data

Funding Support: None

International Collaboration: No
International Travel: No

Candice Young

Email: clyoung@berkeley.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 0

Contribution to the Project: Assisted graduate students collecting data

Funding Support: None

International Collaboration: No

International Travel: No

Katelyn Yu

Email: katelyn.a.yu@gmail.com

Most Senior Project Role: Undergraduate Student

Nearest Person Month Worked: 0

Contribution to the Project: Assisted graduate students collecting data

Funding Support: None

International Collaboration: No

International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Babson College	Academic Institution	Babson Park, MA
Berkeley Natural History Museums	Academic Institution	University of California, Berkeley, CA
Cawthron Institute	Academic Institution	New Zealand
Colorado State University	Academic Institution	Fort Collins, CO
Eel River Recovery Project	Other Nonprofits	Garberville, CA
Friends of the Eel River	Other Nonprofits	Arcata, CA
Gold Ridge Research Conservation District	State or Local Government	Sebastapol, CA
Humboldt State University	Academic Institution	Arcata, CA
Institut de Physique du Globe de Paris	Academic Institution	Paris, France
Karuk Tribe	Other Organizations (foreign or domestic)	Happy Camp, CA
Lawrence Livermore National Lab	Other Organizations (foreign or domestic)	Livermore, CA
NOAA National Marine Fisheries Service Southwest Region	State or Local Government	La Jolla, CA
Bureau of Land Management	State or Local Government	California

Name	Type of Partner Organization	Location
Northern Arizona University	Academic Institution	Arizona
Notre Dame University	Academic Institution	Notre Dame, IN
Penn State	Academic Institution	State College, PA
Redwood Forest Foundation	Other Nonprofits	Mendocino, CA
Rutgers University	Academic Institution	Newark, NJ
Senckenberg Institute	Academic Institution	Frankfurt, Germany
St. Catherine University	Academic Institution	Saint Paul, MN
Swedish University of Agricultural Sciences	Academic Institution	Sweden
The Nature Conservancy	Other Nonprofits	San Francisco, CA
The University of Texas at Austin	Academic Institution	Austin, TX
CA Department of Fish and Wildlife	State or Local Government	California
USFS Caspar Creek Experimental Watershed Study	State or Local Government	Fort Bragg, CA
USGS	State or Local Government	United States
University of Alberta	Academic Institution	Edmonton, Alberta, Canada
University of Arkansas	Academic Institution	Fayetteville
University of California Natural Reserve System	Academic Institution	Oakland, CA
University of California, Davis	Academic Institution	Davis, CA
University of California, Merced	Academic Institution	Merced
University of California, Santa Cruz	Academic Institution	Santa Cruz, CA
University of Illinois, Urbana-Champaign	Academic Institution	Urbana-Champaign, IL
University of Minnesota	Academic Institution	Minnesota
CSU San Marcos	Academic Institution	San Marcos, CA
University of Wyoming	Academic Institution	Laramie, WY
Université de Rennes 1	Academic Institution	Rennes, France

Name	Type of Partner Organization	Location
Watercourse Engineering, Inc.	Industrial or Commercial Firms	Davis, CA
Wright State University	Academic Institution	Dayton, Ohio
CUAHSI	Other Nonprofits	Cambridge, MA
California Department of Forestry and Fire Protection	State or Local Government	California
California Heartbeat Initiative	Other Nonprofits	California
California Sea Grant	Other Organizations (foreign or domestic)	California
Caltrout	Other Nonprofits	San Francisco, California

Full details of organizations that have been involved as partners:

Babson College

Organization Type: Academic Institution

Organization Location: Babson Park, MA

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

Berkeley Natural History Museums

Organization Type: Academic Institution

Organization Location: University of California, Berkeley, CA

Partner's Contribution to the Project:

In-Kind Support

More Detail on Partner and Contribution:

Bureau of Land Management

Organization Type: State or Local Government

Organization Location: California

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

CA Department of Fish and Wildlife

Organization Type: State or Local Government

Organization Location: California

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

CSU San Marcos

Organization Type: Academic Institution

Organization Location: San Marcos, CA

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

CUAHSI

Organization Type: Other Nonprofits

Organization Location: Cambridge, MA

Partner's Contribution to the Project:

Financial support

Personnel Exchanges

More Detail on Partner and Contribution:

California Department of Forestry and Fire Protection

Organization Type: State or Local Government

Organization Location: California

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

California Heartbeat Initiative

Organization Type: Other Nonprofits

Organization Location: California

Partner's Contribution to the Project:

Financial support

Collaborative Research

Personnel Exchanges

More Detail on Partner and Contribution: The California Heartbeat Initiative is a \$2.179 million grant awarded to the UC Natural Reserve System by the Gordon & Betty Moore Foundation to monitor the pulse of water through state ecosystems.

California Sea Grant

Organization Type: Other Organizations (foreign or domestic)

Organization Location: California

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

Caltrout

Organization Type: Other Nonprofits

Organization Location: San Francisco, California

Partner's Contribution to the Project:

Financial support

Collaborative Research

More Detail on Partner and Contribution:

Cawthron Institute

Organization Type: Academic Institution

Organization Location: New Zealand

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

Colorado State University

Organization Type: Academic Institution

Organization Location: Fort Collins, CO

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

Eel River Recovery Project

Organization Type: Other Nonprofits

Organization Location: Garberville, CA

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution: Collaborator on ERCZO Education & Outreach activities.

Friends of the Eel River

Organization Type: Other Nonprofits

Organization Location: Arcata, CA

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution: Collaborator on ERCZO Education & Outreach activities.

Gold Ridge Research Conservation District**Organization Type:** State or Local Government**Organization Location:** Sebastapol, CA**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution:

Humboldt State University**Organization Type:** Academic Institution**Organization Location:** Arcata, CA**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution: Working with Assistant Professor Jasper Oshun (former grad student)

Institut de Physique du Globe de Paris**Organization Type:** Academic Institution**Organization Location:** Paris, France**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution: We are working with J. Bouchez and J. Gaillardet on isotope fingerprints of groundwater

Karuk Tribe**Organization Type:** Other Organizations (foreign or domestic)**Organization Location:** Happy Camp, CA**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution: Collaborator on ERCZO Education & Outreach activities.

Lawrence Livermore National Lab**Organization Type:** Other Organizations (foreign or domestic)**Organization Location:** Livermore, CA**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution:

NOAA National Marine Fisheries Service Southwest Region**Organization Type:** State or Local Government**Organization Location:** La Jolla, CA

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

Northern Arizona University**Organization Type:** Academic Institution**Organization Location:** Arizona**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution:

Notre Dame University**Organization Type:** Academic Institution**Organization Location:** Notre Dame, IN**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution:

Penn State**Organization Type:** Academic Institution**Organization Location:** State College, PA**Partner's Contribution to the Project:**

Collaborative Research

Personnel Exchanges

More Detail on Partner and Contribution:

Redwood Forest Foundation**Organization Type:** Other Nonprofits**Organization Location:** Mendocino, CA**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution:

Rutgers University**Organization Type:** Academic Institution**Organization Location:** Newark, NJ**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution:

Senckenberg Institute**Organization Type:** Academic Institution**Organization Location:** Frankfurt, Germany**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution:

St. Catherine University**Organization Type:** Academic Institution**Organization Location:** Saint Paul, MN**Partner's Contribution to the Project:**

Collaborative Research

Personnel Exchanges

More Detail on Partner and Contribution:

Swedish University of Agricultural Sciences**Organization Type:** Academic Institution**Organization Location:** Sweden**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution: Collaborated on stochastic hydrologic modeling

The Nature Conservancy**Organization Type:** Other Nonprofits**Organization Location:** San Francisco, CA**Partner's Contribution to the Project:**

Financial support

Collaborative Research

More Detail on Partner and Contribution:

The University of Texas at Austin**Organization Type:** Academic Institution**Organization Location:** Austin, TX**Partner's Contribution to the Project:**

Collaborative Research

Personnel Exchanges

More Detail on Partner and Contribution: Working with former grad student, now Assistant Professor Daniella Rempe

USFS Caspar Creek Experimental Watershed Study

Organization Type: State or Local Government

Organization Location: Fort Bragg, CA

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

USGS

Organization Type: State or Local Government

Organization Location: United States

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

University of Alberta

Organization Type: Academic Institution

Organization Location: Edmonton, Alberta, Canada

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution: We worked with A. Oliver (a CZO SAVI funded proposal) on carbon and nutrient exports from the Eel River

University of Arkansas

Organization Type: Academic Institution

Organization Location: Fayetteville

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

University of California Natural Reserve System

Organization Type: Academic Institution

Organization Location: Oakland, CA

Partner's Contribution to the Project:

Facilities

Collaborative Research

Personnel Exchanges

More Detail on Partner and Contribution:

University of California, Davis

Organization Type: Academic Institution

Organization Location: Davis, CA

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution: Collaborating on nitrogen storage in rocks

University of California, Merced

Organization Type: Academic Institution

Organization Location: Merced

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

University of California, Santa Cruz

Organization Type: Academic Institution

Organization Location: Santa Cruz, CA

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

University of Illinois, Urbana-Champaign

Organization Type: Academic Institution

Organization Location: Urbana-Champaign, IL

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution: We are working with Jennifer Druhan on solute evolution (and reactive transport modeling) through the critical zone

University of Minnesota

Organization Type: Academic Institution

Organization Location: Minnesota

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution:

University of Wyoming

Organization Type: Academic Institution

Organization Location: Laramie, WY

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution: Collaborated on geophysical exploration at the Eel River CZO field site

Université de Rennes 1**Organization Type:** Academic Institution**Organization Location:** Rennes, France**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution: We are working with M. Bormans on controls on cyanobacteria.

Watercourse Engineering, Inc.**Organization Type:** Industrial or Commercial Firms**Organization Location:** Davis, CA**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution:

Wright State University**Organization Type:** Academic Institution**Organization Location:** Dayton, Ohio**Partner's Contribution to the Project:**

Collaborative Research

More Detail on Partner and Contribution: Collaborated on toxic algal blooms with Y. Vadeboncoeur.

What other collaborators or contacts have been involved?

The ER CZO collaborates extensively with the labs of Professor Daniella Rempe of UT Austin and Professor Jennifer Druhan of The University of Illinois. Prof Rempe is leading and advising on the bulk of the field research being conducted within the Vadose Zone Monitoring System, and several of her graduate students are conducting thesis work within this system. She is also taking a lead role in developing a new site (Rancho Venada) bringing significant funding from a DOE grant. Prof Druhan and her lab are studying the role of fluid mobility in the development of shale weathering profiles using the Vadose Monitoring System observations. She leads the modeling of the chemical evolution of the critical zone. Both of these collaborators regularly send graduate students and technicians to lead and assist with field campaigns at the VMS. Jesse Hahm has recently taken an assistant professor position at the Simon Fraser University and will remain an active collaborator.

Impacts**What is the impact on the development of the principal discipline(s) of the project?**

The critical zone is a “thing” and, as such, a kind of critical zone science discipline has emerged. The network of US critical zones has shown the necessity and fruitful consequence of scientists working for multiple years at a focal study site across traditionally distinct disciplines: geology, atmospheric science, ecology, tree physiology, microbiology and other fields. At Berkeley this is expressed not only in the diversity of fields the PIs represent, but in the fact that students freely work across disciplines, departments and colleges to gain deep insight into integrated critical zone processes. Strong expertise in existing disciplines is still essential, but now such expertise can spread and gain new perspectives in a critical zone context.

What is the impact on other disciplines?

The emergence of critical zone science, made possible by observatories focused on understanding mechanisms, has attracted many disciplines. The concept of the critical zone as co-evolving entity is now being explored in many disciplines, including hydrology, geomorphology, pedology, geophysics, ecology, and climate science.

What is the impact on the development of human resources?

During the past year, 3 post-doctoral researchers, 10 graduate students and 11 undergraduate students conducted research in the ER CZO. Working through the ER CZO has provided these students with invaluable experience in the practical aspects of designing and conducting research projects as well as access to the broad experiences and perspectives of our PIs and senior personnel. Several of the undergraduates will attend graduate school to pursue related research.

Several of our personnel have attained professional positions related to their work at the ER CZO in the last year, including: 1) David Dralle began an assistant professor position at CSU Sacramento in Spring 2019 2) Jesse Hahm will begin an assistant professor position at Simon Fraser University January 2020.

What is the impact on physical resources that form infrastructure?

The physical infrastructure at our primary field sites, Rivendell and Sagehorn, have roughly 1,000 sensors, 20 loggers, and an extensive wireless infrastructure. We added 44 high power sap flow sensors. This, in combination with a wet and cloudy winter, taxed our power systems. We have upgraded and modernized 11 solar systems. We have increased solar panel power and battery capacity to 150% previous capability. As in previous years, we periodically replace failing equipment to maintain monitoring quality. This infrastructure is essential to the success and on-going work of graduate students and post-doctoral fellows. We collaborated with Professor Daniella Rempe to develop a monitoring program at Rancho Venada (described above).

What is the impact on institutional resources that form infrastructure?

The primary field site for the ER CZO is the Heath and Marjorie Angelo Coast Range Reserve (Angelo). Angelo is one of 40 protected natural areas managed by the University of California Natural Reserve System (UCNRS). These areas are maintained by University for the purposes of research, education and public service. Various monitoring apparatuses exist and many of these sites and the UCNRS as recently committed to making near real-time biological, hydrological and meteorological data available to the broader research community.

The UCNRS has provided salary support to ER CZO personnel Scott Smith (data analyst) Wendy Baxter (field technician) , Collin Bode (data manager), and two field technicians to establish and maintain a network of weather stations and to create a database structure to enable access to various data streams generated at the UC reserves. The database (*Dendra*) effort is being modeled after the ER CZO's sensor database, which Virginia Ogle created, and will continue to be supported by UCNRS beyond the lifetime of the ER CZO award.

What is the impact on information resources that form infrastructure?

During the 2018-2019 funding period, the ERCZO expanded its monitoring infrastructure and made extensive changes to its cyberinfrastructure.

Our data manager, Collin Bode, is working with Lou Derry at the Central Office on the CZOshare data rescue initiative to help all CZOs centralize their datasets and metadata into CUAHSI's HydroShare. Collin, David Lubinski, web developer for the CZO website and Miguel DeLeon, data manager for Luquillo CZO are the core team for this effort. The project has developed controlled vocabularies for CZO datasets and CUAHSI has modified HydroShare to have a "Community" section. The CZO network is the test community for this new feature. The project has successfully copied all publically available datasets from local servers to HydroShare in several test runs. Final transfer occurred in October.

Dendra was launched on May 1st, 2018 and is now in production at <https://dendra.science>. Dendra is our sensor database data curation system. Dendra is hosted on the NSF funded XSEDE supercomputing network. All time-series data is streamed into Dendra in real-time. The system now has the ability to dynamically version datasets – a feature no other system has at this time. Dendra is a collaboration with the University of California Natural Reserve System, hosting their 30 weather station network. A Gordon & Betty Moore Foundation funded project, the 'California Heartbeat Initiative', hosts 10 stations with 40 more planned.

What is the impact on technology transfer?

Nothing to report.

What is the impact on society beyond science and technology?

ER CZO researchers, anchored by Co-I Mary Power, have participated in many outreach efforts. In addition to various speaking engagements and meetings the group has been involved in several long-term collaborative partnerships, some of which are ongoing. ER CZO has strong interactions with the very active citizen's river watch group, the Eel River Recovery Project (ERRP). The ERCZO coordinates and shares data from joint temperature, fish, native frog, invasive snail and crayfish, and algal, cyanobacterial, and cyanotoxin monitoring efforts distributed throughout much of the 9546 km² Eel River basin. These riverine biota are supported or stressed, depending on the nature, timing, and magnitude of delivery of several Critical Zone currencies (water, heat, solutes, and sediments) to channel networks. CZO researchers regularly attend and speak at ERRP watershed meetings, and ERRP members and leaders speak and participate in our short Angelo Reserve courses and workshops.

Educational Videos

Eel River Recovery Project Volunteer and videographer, Barbara Domanchuk, came to UC Berkeley with 2 community college interns to interview and film Keith Bouma-Gregson, Jesse Hahm, and Mary Power about the Eel River CZO, river ecology, and cyanobacterial ecology. This footage has been turned into a series of short science education videos that have been posted on websites and was aired on public TV in Humboldt County. A culminating video, "Cyanobacteria: ancient life in the Eel River ecosystem" is now on featured on the Eel River Recovery Project website.

UC Berkeley Press Release

Graduate student Jesse Hahm's below-ground water storage capacity research was featured on the UC Berkeley news website in a 2019 article, "Does limited underground water storage make plants less susceptible to drought?"

Eos Research Spotlight

Graduate student Jesse Hahm's findings from Hahm et al., 2019 were featured in an Eos: Earth and Space Science News article, "Answer to California Landscape Riddle Lies Underground".

KMUD Radio Interview

Graduate student Jesse Hahm was invited to KMUD's Monday Morning Magazine- Redwood Community Radio to discuss the Oregon White Oak's future and bedrock-plant-stream interactions in the Northern California Coast Ranges.

Sonoma County Sea Grant Collaboration

Graduate student Gabe Rossi coordinated a meeting between CZO researchers and Sonoma County Sea Grant fisheries research staff to discuss a Russian River - Eel River research collaboration.

Pikeminnow Dive

Graduate student Phil Georgakakos and his undergraduate field assistants participated in the Eel River Recovery Project's pikeminnow dive for the 4th year running. They joined and assisted for 2 full days of snorkeling, helping with fish identification and general methods for snorkel surveys.

California Ecology and Conservation

Graduate student Phil Georgakakos gave a talk to the California Ecology and Conservation class when they visited the Angelo Coast Range Reserve in summer 2019.

Changes/Problems

Changes in approach and reason for change

Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them

Nothing to report.

Changes that have a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.