Is Mountain Block Recharge Important in the Sierra Nevada?

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ABSTRACT

We are initiating a student-scientist research project to investigate the sources of water for the upper Merced River, which provides critical aquatic habitat, water for downstream agriculture and cities, and recreation.. Little is known about the partitioning of snowmelt to groundwater recharge in alpine hydrology—especially in the Sierra Nevada, California. During the dry season, major rivers in the Sierra Nevada mountains continue to flow due to groundwater discharge in the drainage basin. During the snowmelt period, the contribution of groundwater to the total flow is unknown. We intend to sample the Merced River, tributaries, and nearby springs and wells, from the headwaters in Yosemite National Park (YNP) to the first reservoir (Lake McClure) to determine the spatial and temporal variability of water chemistry. Our strategy is for schools to take weekly samples at least one site and for university researchers to take samples at multiple locations on a quarterly basis and do detailed analyses. From these data, we intend to establish a spatial and temporal geochemical signature of Merced River water. We aim to evaluate the partitioning of snowmelt between runoff and groundwater recharge. Knowledge of the subsurface reservoir available, time to depletion, and time to recharge are critically needed to estimate catchment response to multi-year droughts.

INTRODUCTION

There are four main scientific motivations for the research. First, both snowmelt and groundwater feed the rivers originates in the Sierra Nevada. The snowmelt can contribute directly to rivers, or recharge the groundwater (see Figure 1). Knowledge of flowpaths (direction and velocity of groundwater flow through porous media) is essential for understanding the chemical composition of streamwater. Knowledge of the sources of water to a river is important for understanding and modeling stream response to atmospheric deposition and climate change. For example, our past efforts at modeling headwater catchment response to changing climate have relied on very uncertain parameterization of subsurface flow paths and residence times (Wolford and Bales, 1996, Meixner et al., 2003a,b). Recent findings that headwater catchment residence times in one central Sierra Nevada catchment were decades suggests that a different approach to modeling the chemical evolution is needed (Rademacher et al., 2001). Use of isotope tracers in one southern Sierra catchment for inferring flowpaths suggested that essentially all flow passed through soil, even though very little of the catchment was mapped as having soil (Huth et al., in press).

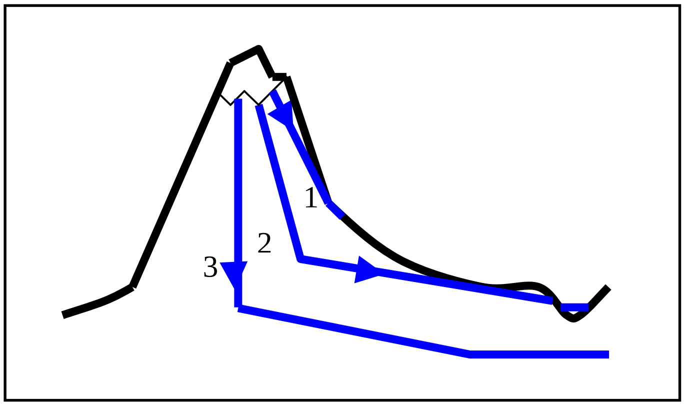

Figure 1. Mountain recharge flowpaths. As the snow melts some water recharges into the bedrock, following fractures. Some flowpaths end up as springs (1), some flowpaths discharge into rivers (2), some flowpaths are “deep groundwater” until geology forces the water to the surface.

Second, subsurface water provides baseflow, which is particularly important source of water to the rivers following snowmelt. Baseflow is the amount of water in the river during the lowest flows, in these systems occurs late summer and fall. Knowledge of the subsurface reservoir available, time to depletion, and time to recharge are critically needed to estimate catchment response to multi-year droughts (e.g. climate variability) and seasonally changing snowmelt (and thence soil moisture and streamflow) patterns.

Third, knowing groundwater residence and circulation rates gives critical information about recharge rates. Although recharge is a small fraction of the water budget (our hypothesis), changing recharge amounts/patterns could indicate large changes in the terrestrial landscape. This study will provide current baseline information and indicate the importance of subsurface vs, surface flowpaths for water traveling from upstream to downstream parts of the basin. This is important for both the mountain water budget, but also for groundwater recharge to valley aquifers.

Fourth, aquatic and riparian communities depend critically on baseflow, just as terrestrial communities depend on soil moisture. Riparian communities are the ecosystem that exists around the river. Aquatic communities are what lives in the river. Macroinvertebrates live in the shallow sediments and water column. If baseflow is reduced, this could affect the flora and fauna in the river system.

PROJECT PLAN

The specific aims of the proposed research are to determine the changing water quality of the Merced River both temporally and spatially. The temporal coverage will be done by schools, the spatial coverage by university researchers. By combining these two sampling regimes will allow us to see how the water quality varies throughout the year. With the detailed analyses (see below) by the university researchers, we aim to i) determine the age of water entering the Merced River and upstream tributaries at various times during the year, and ii) infer flowpaths for water traveling from the headwater catchments to the various tributaries at various times during the year. The initial collaboration between scientists and schools would be students collecting conductivity and water temperature data at various points on the Merced River on a weekly time scale. They will also sample macroinvertebrates at the same sites. The hydrology team will work with the schools to explain the science objectives and work with them to develop science fair projects.

Two educational institutions have agreed to participate with this study, Yosemite Institute (located inside Yosemite Park) and hosts many school groups for week-long sessions, and Yosemite Valley School. Yosemite Valley school has already established a hydrology site and taken a year of data (figure 2). In addition a graduate student at University of California, Merced has taken quarterly water quality measurements of the Merced River from Yosemite National Park to Lake McClure (the first dam on the Merced River).

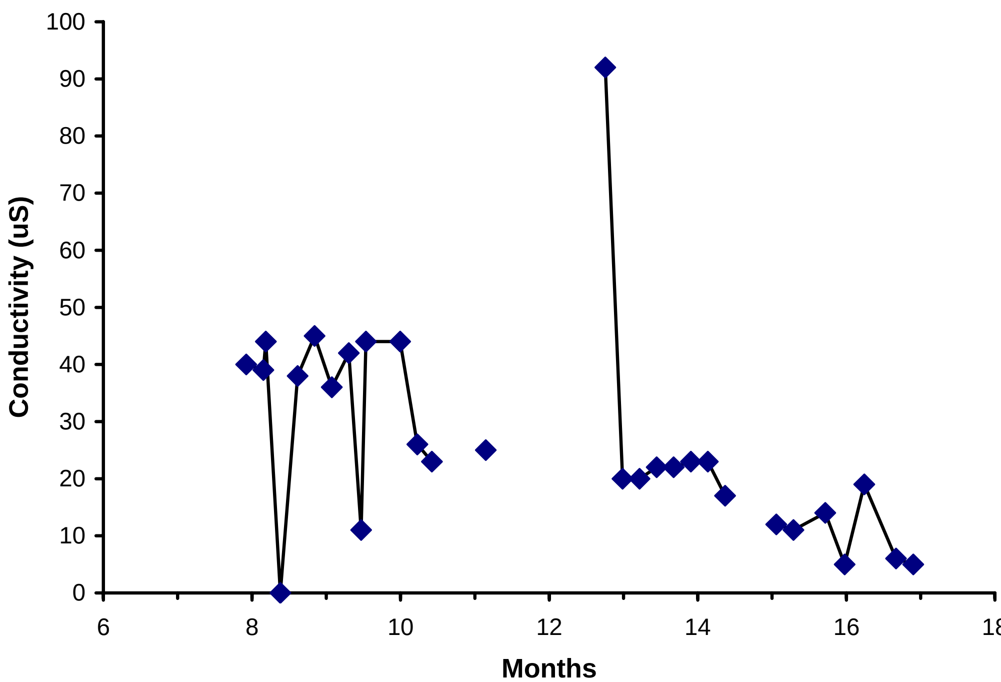

Figure 2. Conductivity data collected by Yosemite Valley School. Conductivity is higher during the dry months and decreases during snowmelt season. Note the high value is questionable.

METHODS

Groundwater residence times are difficult to measure in mountain watersheds due to a lack of monitoring wells and complex systems shallow soil overlying fractured, folded, and faulted bedrock. Isotopes and dissolved gasses are particularly useful because groundwater travel times may be estimated independently of hydraulic conductivity (K) measurements—which vary 13 to 16 orders of magnitude in natural geologic materials (Freeze and Cherry, 1979; Cook and Solomon, 1996; Phillips and Castro, 2003). To test this, some parameters (temperature, conductivity and pH) will be measured on a fine spatial scale along the river. In adjacent reaches that show significant changes in these parameters, more detailed water chemistry analysis will be conducted. These will include stable isotope concentrations (^{2}H, ^{18}O), dissolved gas concentrations (He, Ne, Ar, N_2,

^{3}He, ^{3}H, CFCs, SF_6), radioisotopes (^{3}H, ^{36}Cl, ^{129}I, ^{14}C), silica, major anions, major cations, major nutrients, and physical stream parameters. To obtain information about groundwater composition the same suite of measurements will be collected on springs discharging near the Merced River, and available wells will also be sampled. At minimum, we will collect synoptic samples during, fall, winter, and a more intensive sampling during peak flow (around April), and during the recession to baseflow. Spatial coverage will depend on accessibility. Schools will collect samples at fixed locations on a more frequent basis.

Stable isotopes, ^{18}O and deuterium, in springs and streams will help indicate the fraction of groundwater to snowmelt runoff in the Merced River. Stable isotope data, and noble gas data will be used to infer groundwater recharge elevations. Natural tracer analyses can include chlorofluorocarbons (CFC's), sulfur hexafluoride (SF_6), tritium, noble gases (helium isotopes, neon, and argon), chlorine-36 (^{36}Cl), iodine-129 (^{129}I), and carbon-14 (^{14}C) to provide groundwater age estimates. Other species to be analyzed in springs and streams include conductivity, base cations, and major anions, and nutrients.

The Merced River provides a catchment that is relatively undisturbed—with no significant water diversion until the Central Valley/Sierra Nevada margin. Furthermore, a large percentage of the river reaches are easily accessible by roads, and there is an extensive trail system through the sections that are not available by road, allowing synoptic sampling.

IMPORTANCE AND IMPLICATIONS

Knowledge of groundwater flowpaths and residence times is essential for understanding the chemical evolution of both groundwater and stream water. It provides a more complete picture of flowpaths for nutrients, and possible contaminant transport processes in a watershed. Furthermore, subsurface water provides baseflow to the river, which is particularly important for the seasons following snowmelt. The sampling and analysis will be used to evaluate the partitioning of snowmelt between runoff and groundwater recharge. In addition, this study will provide temporal and spatial snapshots of Merced River water chemistry, establish baseline information, and indicate the importance of subsurface vs, surface flowpaths for water traveling from upstream to downstream parts of the basin. Knowledge of the subsurface reservoir available, time to depletion, and time to recharge are critically needed to estimate catchment response to multi-year droughts. Furthermore, groundwater travel times and flowpaths are critical in evaluating nutrient budgets and cycling as well as solute transport processes in the area. This study may also provide useful information on groundwater residence times that may be able to be scaled up to the represent typical Sierra Nevada Watersheds.

References

Cook, P. G., D. K. Solomon, Recent advances in dating young groundwater: chlorofluorocarbons, $^{3}H/^{3}He$ and Kr, Journal of Hydrology, 191, 245-265, 1997.

Erman, N. A., and D. C. Erman, Spring permanence, Trichoptera species richness, and

the role of drought, Journal of Kansas Entomology Society, 68, 50-64, 1995.
Meixner, T., C. Gutmann, R.C. Bales, A. Leydecker, J. Sickman, J. Melack, J. McConnel, Multidecadal hydrochemical response of a Sierra Nevada watershed: sensitivity to weathering rate and changes in deposition, *Journal of Hydrology* ,272-285, 2003.a

Meixner, T., R.C. Bales, Hydrochemical modeling of coupled C and N cycling in high-elevation catchments: Importance of snow cover, *Biogeochemistry*, 62(3): 289-308, 2003b.

Freeze, R. A., and J. A. Cherry, Groundwater, Prentice Hall, Englewood Cliffs, NJ, 604 pp., 1971.

Nimz, G. J., unpublished data,

Phillips, F. M., and M. C. Castro, Groundwater dating and residence-time measurements, In Treatise on Geochemistry, (ed.) H. D. Holland and K. K. Turekian, vol 5 Surface and Ground Water, Weathering and Soils, (ed.) J. I. Drever, Oxford University Press, Oxford, pp 451-497, 2003.

Phillips, F. M., Chlorine-36, in Environmental Tracers in Subsurface Hydrology, (ed.) P. Cook and A. L. Herczeg, pp 299-348, 2000.

Plummer, L. N., E. Busenberg, J. K. Bohlke, D. L. Nelms, R. L. Michel, and P. Schlosser, Groundwater residence time in Shenandoah National Park, Blue Ridge Mountains, Virginia, USA: a Multi-Tracer Approach, 179, 93-111, 2001.

Rademacher, L. K., J. F. Clark, G. B. Hudson, D. C. Erman, and N. A. Erman, Chemical evolution of shallow groundwater as recorded by springs, Sagehen Basin; Nevada County, California, Chemical Geology, 179, 37-51, 2001.

Wolford, R.A. and R.C. Bales, Hydrochemical modeling of Emerald Lake watershed, Sierra Nevada, California: Sensitivity of stream chemistry to changes in fluxes and model parameters. *Limnol. Oceanog.*, 41(5): 947-954, 1996.