

## **Sediment-transport monitoring using hydrophones on the San Joaquin River and tributaries**

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*Presented at the 2015 San Joaquin River Restoration Program (SJRRP) Science Meeting,  
Los Banos, California, June 11-12, 2015*

The natural hydrologic and sediment transport regime of the San Joaquin River, California, (SJR) has been severely altered by channel and watershed changes such as the construction and operation of Friant Dam, in-stream gravel mining, and bank stabilization. Though traditional bedload sampling has been used in the mainstem SJR to quantify the sediment budget for large reaches of river, additional monitoring is needed to better understand the response of sediment movement and spawning habitat to restoration flows. We developed a low-cost, long-term, sediment monitoring system using hydrophones that enables collection of near-continuous acoustic data as a surrogate for sediment transport. These acoustic data may also be calibrated to physical samples.

The hydrophone monitoring systems were installed in November 2013 at 6 sites in the mainstem SJR (2 of which were co-located with bedload sampling sites operated by the California Department of Water Resources) and 2 sites on ephemeral tributaries. The hydrophone monitoring systems work by recording the sediment-generated noise (SGN) produced by the collisions of coarse sediment (gravel and cobble). Each site is equipped with two hydrophones and one recording system, which is patent pending. As a result of the ongoing drought in California, peak streamflow in 2014 only reached about 1,300 ft<sup>3</sup>/s. The hydrophone monitoring stations are still in the developmental phase; so, to test them during higher flows, we also partnered with the USFWS to install two of these systems during a high-flow event on the Gunnison River, Colorado, in the summer of 2014. We also tested a kayak-mounted hydrophone system in conjunction with an Acoustic Doppler Current Profiler (ADCP) and Global Positioning System (GPS) for three different flows on the Gunnison River and one flow on the SJR.

Transport rates of coarse sediment were very low at most sites (based on results from the hydrophone data at the upstream sites and physical bedload samples collected at two sites). At Skagg's Bridge, the downstream-most hydrophone site on the mainstem SJR (and the site with the smallest median grain size of all hydrophone sites: 26 mm), the hydrophones detected a moderate amount of SGN. Based on the acoustic data, we qualitatively estimated that coarse sediment transport began around 1,050-1,100 ft<sup>3</sup>/s, which was within the range estimated from earlier bedload samples collected by the USGS. The Gunnison River hydrophone systems detected substantial SGN during an event that peaked at 14,000 ft<sup>3</sup>/s, and detected hysteresis patterns of sediment transport which may get missed by using only physical sampling. Results from the mobile hydrophone system enabled us to map the location and relative magnitude of SGN. In general, the hydrophones perform well under a variety of conditions in the field for months at a time and over a range of flows, and we will continue monitoring and working on techniques to calibrate SGN to physical samples and identify threshold conditions. The spatial hydrophone data when coupled with in-situ hydrophone monitoring data can provide a unique and comprehensive understanding of the response of sediment transport and salmon spawning habitat to restoration flows.