Updates and Improvements to the Arroyo de los Pinos Research Station

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Abstract

This document describes updates that have been made to the Arroyo de los Pinos sediment research station since the last Conference on Sedimentation and Hydrologic Modeling (SedHyd 2019). The research station, located in Socorro, New Mexico, was developed to study sediment transport in ephemeral streams using physical and surrogate methods. The station has been documented in conference papers, student theses, and journal articles. These new methods and analyses include surface velocity measurements, impact microphone modifications, slot sampler lid to selectively sample bedload at peak flow, seismic node deployment and signal analysis, rainfall-runoff analysis and characterization in the basin, tributary delta interactions with the trunk stream using photogrammetry, and the catalog of physical samples collected over approximately seven years. Other conference papers at SedHyd 2023 discuss more specific analysis of data collected at the Arroyo de los Pinos sediment research station.

Introduction

The Arroyo de los Pinos station is a state-of-the-art research facility located in Socorro, New Mexico (Figure 1). The ephemeral basin, which drains to the Rio Grande, was selected in 2015 as a site to study sediment transport in ephemeral streams (Varyu 2020). Sediment contributions from ephemeral tributaries have been identified as a major source of uncertainty when attempting to conduct a sediment budget for the Middle Rio Grande due to the complications inherent in monitoring water and sediment in flashy ephemeral streams (Reclamation, 2012, Tetra Tech 2013).

The research station has been described previously (Varyu, 2019, Stark et al. 2021) and is briefly discussed here. Various journal articles and student theses/dissertations have captured the analysis conducted with the collected data (Varyu 2020, Stark et al. 2021).

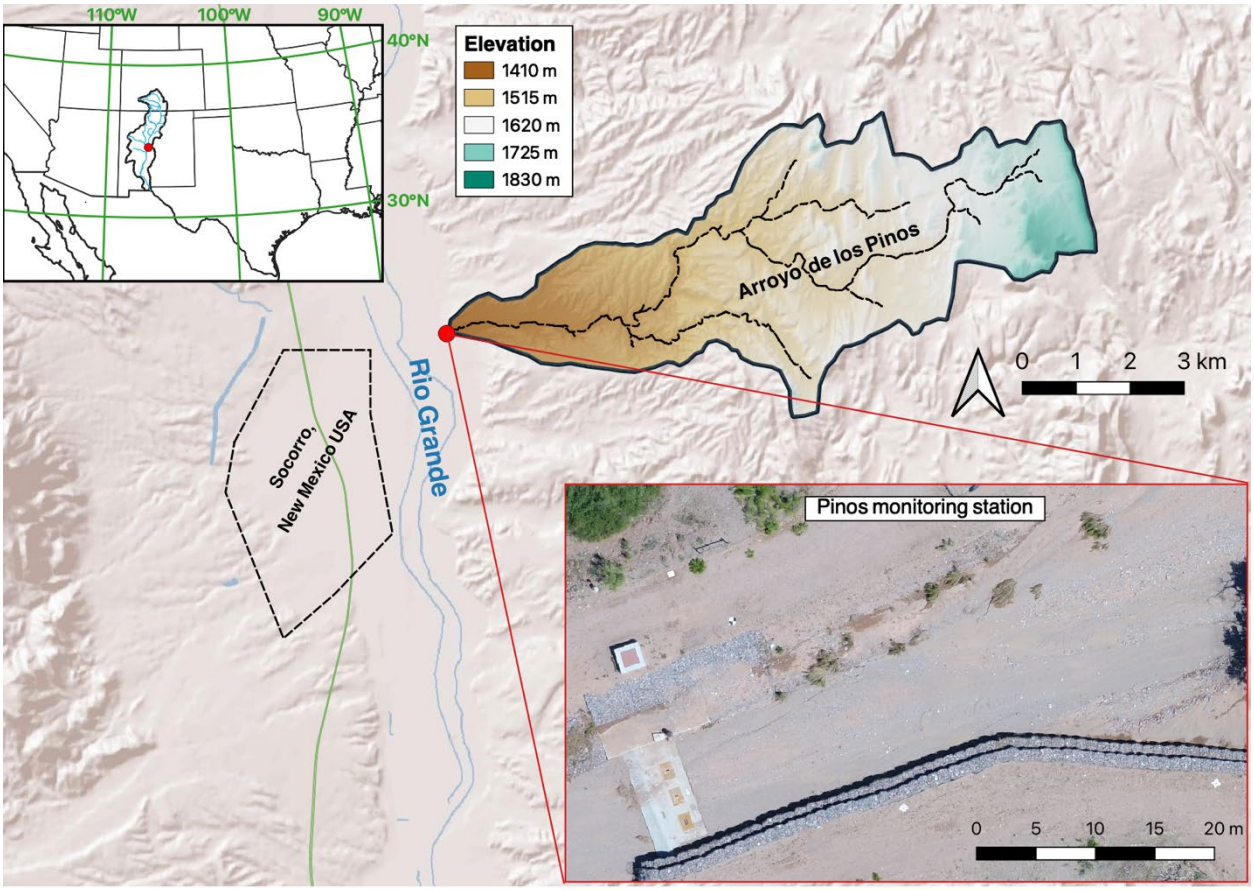

Figure 1. Study site and research station at the Arroyo de los Pinos (courtesy K. Stark)

Site Description and Methods

The intention of the Arroyo de los Pinos sediment research station has been to compare surrogate techniques for monitoring sediment transport against definitive physical samples in an ephemeral system. The long-term goal is to identify surrogate techniques that can be deployed at lower cost (relative to physical sampling) which can improve confidence in sediment loadings to trunk streams from ephemeral tributaries.

Bed load samples are collected with three Reid-type automatic slot samplers situated below a concrete sill that spans the width of the channel. Suspended sediment is collected at the right bank of the channel using two ISCO pump samplers with inlet tubes at different vertical distances from the concrete sill. Along with these physical samplers, surrogate sediment monitoring techniques that have been operating since site construction include bedload sensing active pipe and plate microphones located in the concrete sill upstream of the slot samplers, high-end turbidity sensors, and broadband seismometers. Additional data collection at the site includes pressure transducers for flow depth, manual velocity measurements across the channel width, bed material sediment sampling, photogrammetry of the channel using drone imagery, and terrestrial lidar scans. Additions and adjustments have been made in recent years to improve the quantification of hydraulics and sediment transport rates during monsoonal flood events.

Both handheld radar and mounted stationary Large-Scale Particle Image Velocimetry (LSPIV) camera have been implemented to improve the quality of the rating curve at the research station and to derive the variation of roughness with stage (Figure 2). These non-contact techniques have extended the range of flows that can be monitored when flows are too deep and fast to collect ADV measurements in the channel. Although radar and LSPIV aren't new technologies for perennial systems, their application to semi-arid ephemeral streams is rare in the literature.

Figure 2. Instruments added to site for surface velocity measurements: mounted LSPIV camera in protective housing; Inset is of handheld radar

The pipe microphones situated upstream of the left and right slot samplers have yielded fair correlations to the calculated physical bedload discharges. The plate microphone upstream of the center sampler has not performed well. Part of the research was to assess the limits of the plate microphone, and we have determined that this method is sub-optimal for the bed material grain size occurring in the Pinos due to the considerable deposition by sediment lobes covering the plate during events. The center plate microphone has been supplanted with a pipe microphone and was operational during the 2022 monsoon season (Figure 3).

Figure 3. Graduate student Loc Luong testing center pipe microphone after installation, replacing the previously-deployed plate microphone

One of the limitations of the slot samplers is their physical size. The samplers typically fill during the rising limb of a storm event and precludes the correlation of surrogate data to physical samples during the most intense portion of the flow, or to data collected during the falling limb of a storm event. A removable lid has been designed to fit over one of the slot samplers and will be manually removed during storm events (Figure 4). This method was attempted during one of the 2022 monsoon events, but the cable disconnected from the lid during operation, so bedload transport rates were not obtained in that slot sampler during that event. This lid and cable system have been improved and will be ready for the 2023 monsoon season.

Figure 4. Lid covering the right slot sampler so that selective bedload sampling can occur during the peak of a storm event

In addition to impact-style microphones, seismic sensors are being explored as another surrogate method for bedload discharge, a result of international partnerships and an NSF research grant. Five broadband seismic sensors and nearly 70 seismic nodes (smaller frequency range devices) have been deployed at various times in various configurations (Figure 5) to assess seismograms and derived power spectral density data as surrogates for bedload flux. There are three papers at this SedHyd conference related to the seismic instruments at the Pinos and the associated analysis:

- “Field Methods and Instrument Types for Using Seismic Monitoring of Bedload in Sand-Rich Gravel Bed Ephemeral Channels” (McLaughlin et al. 2023)
- “Overview of Bedload Estimates Based on Seismic Monitoring at the ephemeral Arroyo de los Pinos tributary of the Rio Grande, New Mexico” (Bilek et al. 2023)
- “Quantifying bedload transport in ephemeral channels using seismic methods” (Luong et al. 2023)

These papers discuss signal processing, correlation between power spectral density and measured bed load, and the application of a physics-based transport model that uses seismic-derived data to inform a sediment transport model.

Figure 5 Location of the in-channel sediment monitoring research station (blue rectangle) and distribution of the seismic stations deployed during 2021 along the channel. Purple circles are seismic nodes; P1MS and GBB are broadband stations. (Courtesy S. Bilek)

Eleven rain events between 2020 and 2021 were monitored using five rain gages and analyzed relative to basin geology and lithology for thirteen subbasins. Results and discussion on this topic can be found in “Controls on the runoff response of the ephemeral Arroyo de los Pinos watershed to high-intensity rain”(Cadol et al. 2023).

Repeat drone surveys of the channel near the station are collected after each event. Recently, the Rio Grande has been lower than usual and there have been a sequence of imagery that show both the Pinos delta as well as the bed of the Rio Grande (Figure 6). The deposits at the lowermost Pinos area have been trenched and described. This dataset has provided the opportunity to characterize not only the changing bed of the Pinos, but also the fluvial interactions between the tributary and trunk stream. More information on this analysis can be found in: “Sediment transport and morphology at ephemeral tributary junctions”(Laronne et al. 2023)

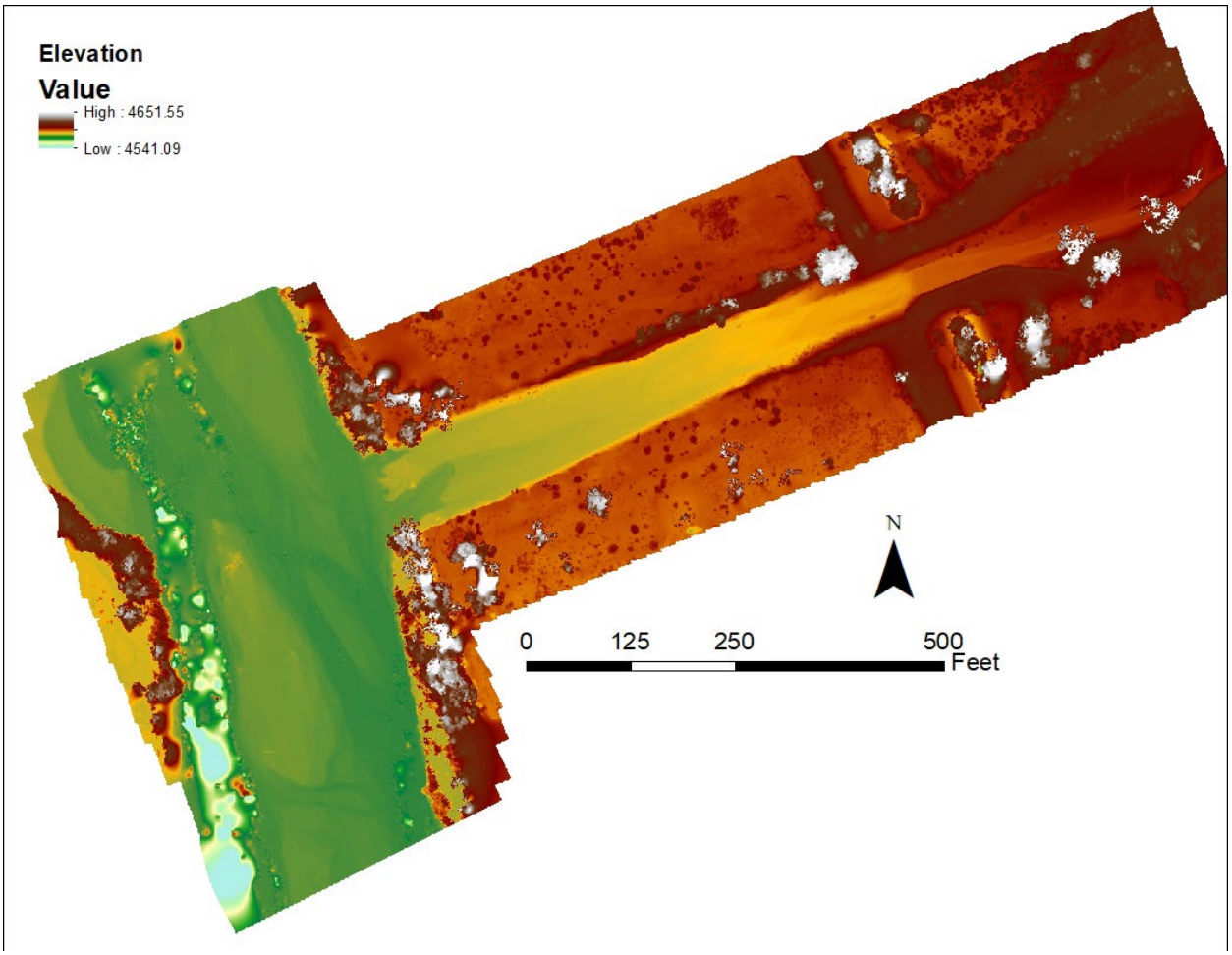

Figure 6 Example DEM of the Pinos delta including the Rio Grande confluence

Surrogate techniques cannot be assessed without a robust set of physical sediment transport data. The long-term and highly accurate physical samples collected at the Pinos research station remains its most valuable asset. Quantification and discussion of the dataset relating to physical measurements can be found in “Seven years of sediment measurements at the Arroyo de los Pinos monitoring station” (Stark et al. 2023).

The robust set of physical measurements at the Arroyo de los Pinos research can be compared to predictive transport models. There are many bedload transport equations in the literature, most of which have been derived from data collected in perennial streams. An assessment of measured transport rates in the Pinos to select predictive equations can be found in “Bedload Transport in Ephemeral Stream” (Moskal et al. 2023).

Conclusion

Highly accurate data continue to be monitored in real time in an ephemeral stream that supplies sand- and gravel-sized sediment to the Middle Rio Grande. These data include those obtained by direct, physical methods as well as surrogate techniques that can be evaluated for accuracy. The eventual results of this data collection and analysis efforts will lead to higher-confidence estimates of sediment transport and sediment delivery rates from ephemeral streams to mainstem rivers using demonstrated techniques in the semi-arid Southwestern United States and similar areas worldwide.

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