Multi-faceted approach to advancing basin-scale sediment source and transport models

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Abstract

Excess sediment is one of the leading causes for river reach impairment in the U.S. While the negative impacts of excess sediment on the environment and infrastructure are numerous, sediment also plays a critical role in maintaining a healthy aquatic ecosystem. To effectively manage sediment in the landscape and mitigate water-quality impairment from excess fine sediment loading, it is imperative to understand and quantify the dominant sediment sources and transport processes that contribute fine sediment to streams. Landscape and stream monitoring paired with modeling strategies can further inform our understanding of the two predominant contributors of fine sediment to streams: upland and in-channel sources. Landscape and stream monitoring efforts are often limited in geographic extent due to cost and field logistics, whereas basin-scale sediment source and transport models can predict basin-scale sediment dynamics at an annual scale but often do not distinguish between upland and in-channel sediment sources. Improvement of basin-scale sediment models that can identify and estimate the contributions from upland and in-channel sources is needed to 1) better inform land managers to prioritize sediment mitigation strategies, 2) understand and predict the effectiveness of mitigation strategies, and 3) understand and predict the transport and fate of sediment and sediment-related contaminants like salinity and phosphorus, and their response to climate change.

As part of a new project to model suspended sediment in three geographically diverse regions—the Delaware River, Illinois River, and the Upper Colorado River basins—we have developed a

multi-faceted approach to improve upon existing sediment source and transport models and move towards a modeling framework that will allow for the prediction of fine sediment at a range of geographic locations. First, we are using high-resolution DEMs to derive landscape openness at channels and slope-area indices to better describe channel geomorphology. Second, we are examining hysteresis in the three basins where continuous turbidity and discharge data are available to help inform potential sediment sources and mechanisms controlling sediment export dynamics and watershed connectivity. Additionally, the hysteresis analysis will be used to derive model variables to help predict sediment response to changing discharge, and to determine whether hysteresis characteristics can be generalized based on watershed and climatic data. Third, building off previous machine learning (ML) sediment transport work at the U.S. Geological Survey, an artificial intelligence machine learning (AI-ML) model is being built using daily climatic and hydrologic data along with watershed characteristics to improve data-driven insights on sediment sources and transport. An AI-ML approach was selected because of its ability to learn complex patterns among data, including antecedent conditions, and allow us to engineer features to improve sediment predictions. By providing daily soil moisture, rainfall, storm duration and intensity information along with other watershed and land use characteristics we hope to gain insight into differences in sediment sources and transport processes over time in the different basins. Fourth, sediment budgets and fingerprinting analysis in smaller sub-basins will be analyzed and used to check model predictions of sediment source and the usefulness of different metrics of landscape openness at channels in predicting sediment source. Fifth, we are using available spatial data combined with an understanding of sediment transport theory to derive a CONUS-scale map of dominant processes which will serve as another check on the model results and as a future guide for building predictive sediment models. The dominant processes map will identify catchments as either net sources or net sinks of sediment and provide a list of potential dominant sediment transport processes. We are hopeful that these integrated efforts will enhance our ability to both understand and predict fine sediment sources and transport in a range of geographic locations.