Landscape-scale variability in stream substrate size: a GIS-based model

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Abstract. Channel substrate is a primary component of the physical habitat "template" that influences stream disturbance regimes and biotic assemblages. Controls on stream substrate characteristics are very complex and operate at many scales. This complexity makes prediction of drainage network-scale patterns in substrate characteristics with geospatial data a very challenging problem. In this study, we use field data from 220 minimally disturbed sites in the Pacific Northwest US to calibrate GIS-based models for predicting median grain size (D_{50}) in streams across the landscape. Starting from a basic conceptualization of key hydrologic and geomorphic drivers, we develop hypotheses regarding the most important descriptors for inclusion in the models. We anticipated that channel slope-drainage area (stream power surrogate), valley entrenchment / hillslope connectivity, discharge magnitude and variability, and potential for grain size punctuation via "significant" tributaries would be the principal predictors of D_{50}. Cross-validated classification tree models were developed for screening out sand and bedrock channels, and regression models were limited to gravel through boulder sized material. Best subsets regression was used to identify several competing GIS-based models that do not require inputs of field survey data. The final model (adj.-R^2=0.36, $p < 10^{-3}$) is physically intuitive, and contains variables representing channel slope, peak discharge, floodplain presence and extent, coefficient of variation in daily discharges, and a measure of water yield per unit watershed area. The increasing prevalence of high-resolution geospatial data may lead to models with improved predictive power and allow substrate size prediction across entire drainage networks with minimal field calibration.

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