Channel Bed Roughness in a Cellular Automata Model of Steep Rough Streams: Varying with Particle Size Distribution, Bed Width, Slope and Particle Mobility

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Abstract. In order to explore the interactions of stream channel form and roughness as bed width, slope, particle size distribution, and particle mobility vary, we present results from a cellular automata model. The model simulates transport of mixed size sediment in steep stream channels, modeled on pool-riffle, plane bed, and step-pool channels. We report the steady state roughness of the bed as bed width, slope, particle size distribution and particle mobility vary. Particle mobility has the greatest effect on bed roughness and both the simulated roughness and surface particle size distribution connect mobility variations to the particle size adjustments observed in a 'gravel front' in which small differences in mobility generate a surface particle size transition from an upstream gravel bed to a much finer bed downstream. The model also reproduces the bimodal particle size distributions located between the gravel and fines-dominated domains, documented in field studies. The modeled transitions in surface particle size distribution occur with relatively minor differences in Shields number. Roughness variation with varying width of the particle size distribution was the second most influential variable in determining bed roughness in the model. With a coarse, narrow particle size distribution, the finest particles tend to become buried, and the surface roughens. Conversely, fine particles are preferentially exposed on the bed when the particle distribution is wide, resulting in a smoother bed. Modeled bed roughness increased with channel slope, and the adjustment is accompanied by a slope reduction, and the adjustment is greater, the steeper the initial slope. Bed roughness increases with an increase in the surface area of the model domain, representing a variation in the size of a homogenous reach. The dependence of roughness on area is interpreted as reflecting a greater likelihood of observing large roughness elements when the surface is large. Our results show that roughness increased more strongly with an increase in bed width than in reach length. The time required for bed roughness to stabilize varied most strongly with increasing particle mobility and slope.