Magnitude - Frequency analysis revisited: Effective discharge for gravel bedload in Rocky Mountain streams shifts to highest recorded flows when based on accurate transport relations

Kristin Bunte[1], Dan A. Cenderelli, Kurt W. Swingle, Steven R. Abt
Department of Civil and Environmental Engineering, Colorado State University

Abstract. Effective discharge (Q_{eff}) computed from a magnitude-frequency analysis (Wolman and Miller 1960) is often reported to correspond with bankfull or the 1.5-year return flow $Q_{1.5}$. Because Q_{eff}, by definition, transports the majority of all bedload, it is considered a design flow for stream restoration and flow management. This study investigates the relationship between Q_{eff} and $Q_{1.5}$ for gravel bedload in 17 Rocky Mountain coarse gravel-bed streams with 30-50 year flow records. Power functions describe both the flow frequency distribution ($F_Q = c\ Q^{-a}$) where Q is discharge class, and the bedload transport (Q_B) rating curve ($Q_B = d\ Q^{b}$). The product $F_Q \cdot Q_B = (d \cdot Q^{-a+b})$ is positive if $b + -a > 0$, and negative if $b + -a < 0$. In log-log plotting scale, power function flow-frequency distributions F_Q exhibit a breakpoint and steepen in the vicinity of $Q_{1.5}$. If the bedload rating curve exponent is small, e.g., =3 as is typical of Helley-Smith bedload samples, $b + -a$ shifts from >0 to <0 at the breakpoint, causing $F_Q \cdot Q_B$ to peak, and $Q_{eff,HS} \cong Q_{1.5}$. More representative measurements of gravel transport obtained from bedload traps and similar devices indicate much larger rating curve exponents of 6-18. In this case, $b + -a$ remains >0 over the entire range of Q, and $F_Q \cdot Q_B$ reaches its maximum near the highest flow on record. Q_{eff} occurred within 46-149% $Q_{1.5}$ for all study streams when computations were based on Helley Smith samples. By contrast, the steeper rating curve exponents typical of bedload trap samples shifted Q_{eff} to Q_{max}. The results suggest that the often-quoted similarity of Q_{eff} and $Q_{1.5}$ is an artifact of using Helley-Smith measurements in mountain streams, and that flow much higher than "bankfull" transport the majority of longterm gravel transport.

[1] Engineering Research Center
Department of Civil Engineering
Colorado State University
Fort Collins, CO 80523-1372
Tel: (970) 491-3980
e-mail: kbunte@engr.colostate.edu