Comparison of Measured Bedload with Predictions from Transport Equations in an Unarmored Ephemeral Channel

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Abstract

The Arroyo de los Pinos is a tributary that transports sediment into the Rio Grande annually through flash flood events.

A wide range of data collected at this site enables assessment of predicted bedload using a wide range of well-established equations that are calculated in a program called BedloadWeb.

We can compare the quality of prediction to the observed bedload transport at a range of flow depths between 5 – 50 cm.

The best fitting bedload transport equations for the Arroyo de los Pinos are the Meyer-Peter and Müller and the Wilcock and Crowe equations.

Equations Tested

Definitions of Dimensionless Parameters

Shields Number: $\tau^* = \frac{\tau}{g(\rho_s - \rho_w)D}$

Dimensionless Transport : $W_i^* = \frac{(s-1)gq_v}{F_i u_*^3}$

Einstein Parameter: $\Phi = \frac{q_v}{\sqrt{g(s-1)D^3}}$

τ = Bed shear stress (N/m^2)
g = Gravity (m/s^2)
ρ_s = Sediment density (kg/m^3)
ρ_w = Water density (kg/m^3)
D = Grain size diameter (m)
$s = \rho_s / \rho_w$ Relative density (-)
q_v = Bedload flux (m^3/sm)
F_i = Fraction of bed covered by grain size class i (-)
u_* = Shear velocity (m/s)

Empirical Bedload Equations

Meyer-Peter and Müller 1948: $\Phi = 8\left[\left(\frac{n'}{n}\right)^{3/2}\tau_* - 0.047\right]^{\frac{3}{2}}$

Parker 1990: $W_i^* = 0.00218\,G(\phi)$

$$G(\phi) = \begin{cases} 5474\left(1 - \frac{0.853}{\phi}\right)^{7.5}, & for\ \phi > 1.59 \\ \exp[14.2(\phi-1) - 9.28(\phi-1)^2], & for\ 1 \le \phi \le 1.59 \\ \phi^{14.2}, & for\ \phi < 1 \end{cases}$$

Wilcock and Crowe 2003:

$$W_i^* = \begin{cases} 0.002\phi^{7.5}, for\ \phi < 1.35 \\ 14\left(1 - \frac{0.894}{\phi^{0.5}}\right)^{4.5}, for\ \phi \ge 1.35 \end{cases}$$

$$\phi = \frac{\tau}{\tau_{ri}}$$

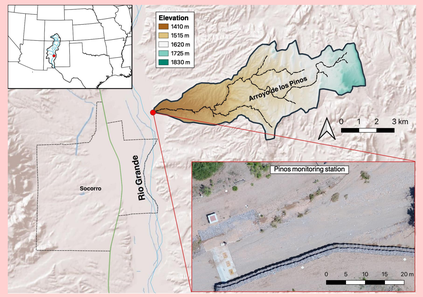
τ_{ri} = reference shear, for grain size bin *i*

The Einstein-Brown equation:

$$\Phi = \left[\sqrt{\frac{2}{3} + \frac{36v^2}{g(s-1)D^3}} - \sqrt{\frac{36v^2}{g(s-1)D^3}}\right]F(\tau_*)$$

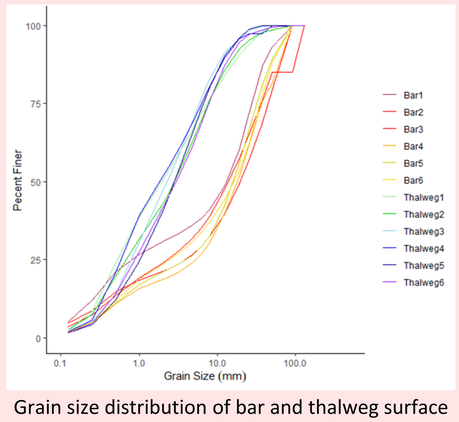
Field Site

The Arroyo de los Pinos within the upper Rio Grande watershed.

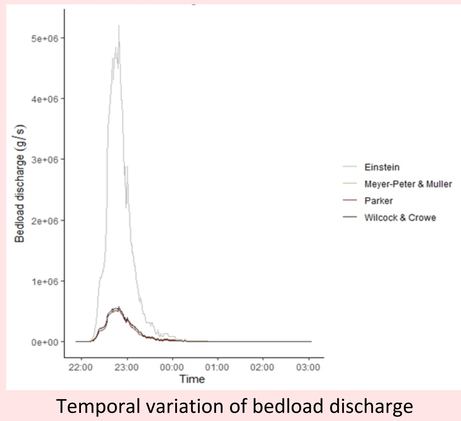


The Arroyo de los Pinos basin and the Pinos monitoring station.

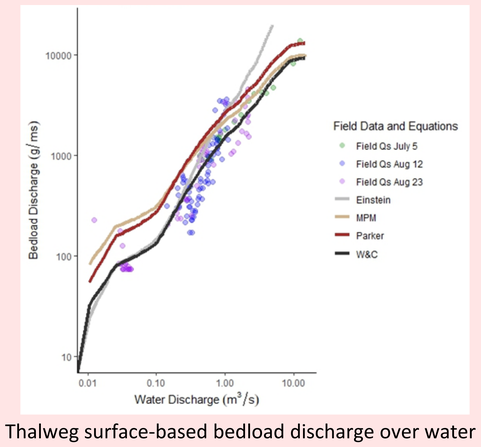
Results



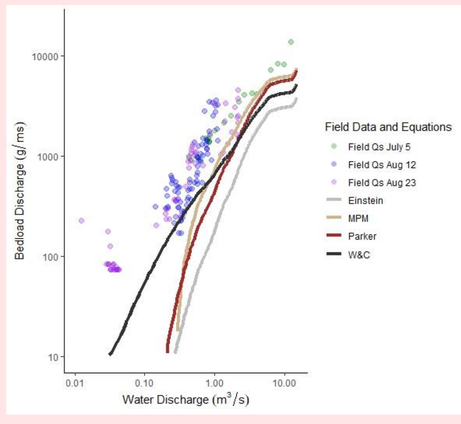
Grain size distribution of bar and thalweg surface samples in the Arroyo de los Pinos.



Temporal variation of bedload discharge according to the four equations.



Thalweg surface-based bedload discharge over water discharge for each flow event with equation estimates.



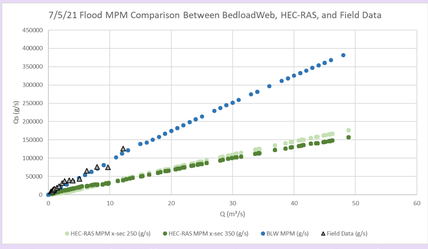
Bar surface-based bedload discharge over water discharge for each flow event with equation estimates.

Conclusions

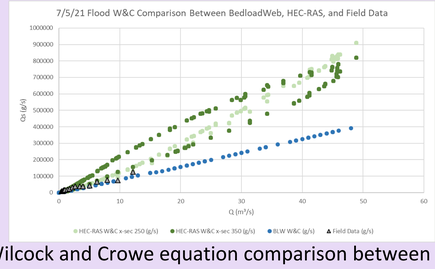
- The Einstein equation overestimates bedload transport.
- The thalweg surface samples match the bedload curves better than the bar surface samples.

Future Work

Use BedloadWeb and HEC-RAS to compare how well each program predicts bedload transport.



Meyer-Peter and Müller equation comparison between BedloadWeb, HEC-RAS, and field data for 7/5/21 flood.



Wilcock and Crowe equation comparison between BedloadWeb, HEC-RAS, and field data for 7/5/21 flood.

References

Recking, A. (2020, January 1). BedloadWeb Concepts and Equations for bedload computation. https://en.bedloadweb.com/ . Retrieved November 19, 2022, from https://en.bedloadweb.com/The%20equations.pdf

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