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Closure to "Variable Shields number model for river bankfull geometry: bankfull shear velocity is viscosity-dependent but grain size-independent" by CHUAN LI, MATTHEW J. CZAPIGA, ESTHER C. EKE, ENRICA VIPARELLI, and GARY PARKER, J. Hydraulic Res. 53(1), 2015, 36–48

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as stated earlier. Again the hidden variables are contained in S and they include viscosity and mean flow velocity.

Regrettably, the Authors were led astray by their hypothesis when they continued to state that their relationship shows how viscosity can enter the problem across scales with their Eq. (9). However, the Discusser needs merely to note that this is their Eq. (7a) divided on both sides by $D_{bank}^{*1/2}$. By that method, any relationship can be shown to be related to any nondimensional quantity.

Although the Authors' conclusion that bankfull shear velocity is dependent on viscosity was not convincing to the Discusser, they were fortunate in the fact that β did include viscosity in its derivation, and their relationships are dimensionally homogenous, therefore the application of the resulting set of equations was not affected.

Finally, the Discusser found it troublesome that the Authors believe the Chezy equation is superior to Manning's equation and that in some way the Chezy coefficient is more capable of quantifying bedform resistance and sinuosity. They conclude the argument by stating that Manning's n needs to be specified with site-specific information while their own empirical relationship derived using site-specific data did not suffer this limitation. The Discusser is most interested in an elaboration from the Authors about why the Chezy coefficient is superior. As a final remark on this, the Discusser does not suggest theoretical superiority of one over the other, but observes that the Manning's n is supported by a lengthy history of use and reference values for various engineering surfaces and natural channel types (Yen, 2002).

The Discusser hopes the criticism will not reduce the impact of the Authors' work in demonstrating the power of a variable Shields number model in comparison to one of constant Shields number. It should be taken as a caution in using dimensional analysis and how relationships between the groupings are developed and interpreted. Dimensional analysis is a truly powerful tool in the physical sciences; however, the burden falls on the analyst to correctly specify all relevant independent quantities for the phenomena to be described. Great care must be taken or else the analysis will fail. In this case, the Authors attempted with reason to describe u_{*bf} as only a function of D^*, but as Eq. (D1) shows, there are other independent, non-superfluous quantities that are necessary in describing u_{*bf}. The Authors believed that because the Shields diagram is described only in terms of D^* they could generally describe τ_{bf}^* and by analogy u_{*bf} as such, but the failure was to recognize that the Shields diagram does not describe τ_{bf}^* but instead a limiting relationship between τ_{bf}^* and D^* for which particle motion is pending.

References

Rouse, H., Koloseus, H. J., & Davidian, J. (1963) The role of the froude number in open-channel resistance. *Journal of Hydraulic Research*, *1*(1), *1963*, 14–19. doi:10.1080/00221686309500064

Sturm, T. W. (2001). *Open Channel Hydraulics*. Boston, MA: McGraw Hill.

Yen, B. C. (2002). Open channel flow resistance. *Journal of Hydraulic Engineering*, *128*(1), 20–39.

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The Authors thank Jared W. Barr for valuable and stimulating feedback. We provide several remarks to address the Discusser's comments.

1. "The Discusser was unable to reproduce $m = 0.534$ in the relation $\tau_{bf}^* \sim S^m$ by performing ordinary least square regression for each grain size group." This point merits discussion, particularly in so far as the Discusser has allowed us to identify and correct an error in our analysis. The methodology we used to determine m was as follows. We regressed the logarithm of τ_{bf}^*/S^m against the logarithm of D^* for various values of m, using the linear regression formulation built into Microsoft Excel. We chose the value $m = 0.534$ because it resulted in the maximum value of the coefficient of determination R^2. This method, however, invariably yields a value of m such that $\tau_{bf}^*/S^m \sim (D^*)^{-1}$, corresponding to a perfectly inverse correlation between D^{-1} in the denominator of $\tau_{bf}^* = \tau_{bf}/(\rho RgD)$ and D in the numerator of $(Rg)^{1/3}D/(\nu)^{2/3}$. We have corrected our analysis using the multiple linear regression tool in the Microsoft Excel 2010 Data Analysis Add-In. Our corrected relationship is:

$$\tau_{bf}^* = 502\, S^{0.434}\, (D^*)^{-0.951} \tag{C2}$$

That is, Eq. (5) of our original paper (abbreviated below to OP) should be replaced with Eq. (C1) of our reply to the Discussion (abbreviated below to RD).

There is little quantitative difference between OP Eq. (5) and RD Eq. (C1). We illustrate this in Fig. C1, which shows the observed values of τ_{bf}^* on the horizontal axis, and the values of τ_{bf}^* predicted from OP Eq. (5) and RD Eq. (C1) on the vertical axis. Eqs (7a) and (7b) of OP change to Eqs (C2a) and (C2b) below:

$$\tilde{u}_{*bf} = 22.4\, S^{0.217}\, (D^*)^{0.0245} \tag{C3a}$$

$$\tilde{H}_{bf} = 502\, S^{-0.566} (D^*)^{0.049} \tag{C3b}$$

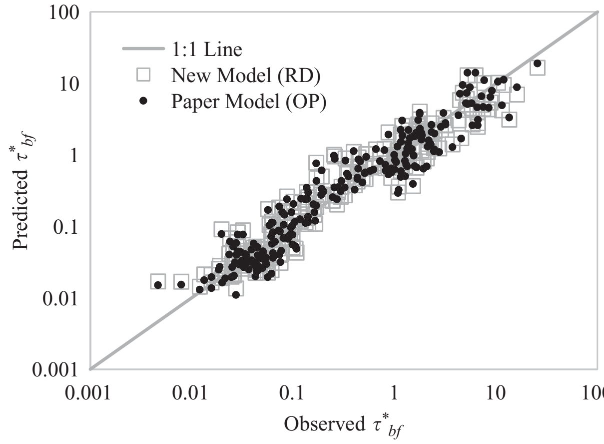

Figure C1 A comparison of observed τ^*_{bf} to predicted versions of the original paper (OP) and the reply to discussion (RD). Data are plotted against a 1:1 slope line that indicates deviations from perfect agreement between observed and predicted values

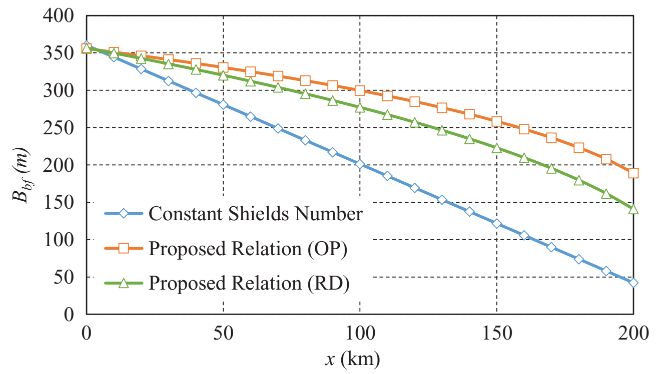

Figure C2 Model predictions for the downstream variation of bankfull width for the Fly-Strickland River system under conditions of steady-state response to constant sea level rise. Results are shown for the constant bankfull Shields number model and the proposed variable bankfull Shields number model of the original paper (OP) and the reply to Discussion (RD)

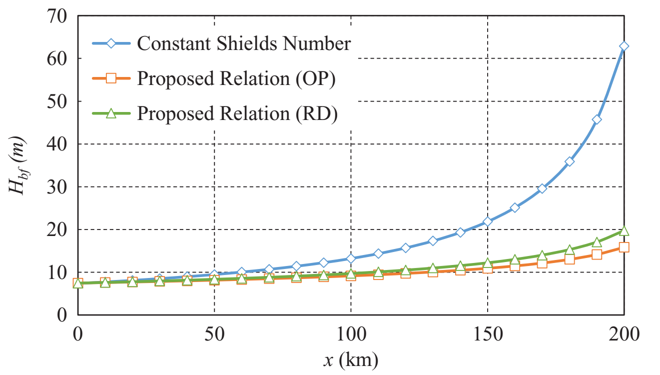

Figure C3 Model predictions for the downstream variation of bankfull depth for the Fly-Strickland River system under conditions of steady-state response to constant sea level rise. Results are shown for the constant bankfull Shields number model and the proposed variable bankfull Shields number model of the original paper (OP) and the reply to Discussion (RD)

In light of Eq. (C2) above, the title of the paper should be amended. Specifically, the text "bankfull shear velocity is viscosity dependent but grain size-independent" should be modified to "bankfull shear velocity is viscosity dependent but *very nearly* grain size-independent" (we use italics to emphasize the change).

Modest modifications propagate through the paper. Equations (18a), (18b) and (18c) of OP now take the respective modified forms:

$$\frac{B_{bf}}{D} = \frac{1}{\alpha_{EH}\sqrt{R}\,\alpha_R^2\beta^{2.5}(D^*)^{2.5n}}\left[\frac{R}{\alpha_{EH}\alpha_R\beta D^{*n}}\right]^{-(2.5m-2n_R)/(1+m-n_R)} \times \left(\frac{Q_{tbf}}{Q_{bf}}\right)^{-(2.5m-2n_R)/(1+m-n_R)} \frac{Q_{tbf}}{\sqrt{gD}\,D^2} \quad \text{(C4a)}$$

$$\frac{H_{bf}}{D} = \alpha_{EH}\alpha_R\beta^2(D^*)^{2n}\left[\frac{R}{\alpha_{EH}\alpha_R\beta D^{*n}}\right]^{(2m-n_R)/(1+m-n_R)} \times \left(\frac{Q_{tbf}}{Q_{bf}}\right)^{(2m-n_R)/(1+m-n_R)} \frac{Q_{bf}}{Q_{tbf}} \quad \text{(C4b)}$$

$$S = \left[\frac{R}{\alpha_{EH}\alpha_R\beta D^{*n}}\right]^{1/(1+m-n_R)} \left(\frac{Q_{tbf}}{Q_{bf}}\right)^{1/(1+m-n_R)} \quad \text{(C4c)}$$

where $m = 0.434$, $n_R = 0.19$, and $n = -0.951$, and Eqs (22a), (22b) and (22c) of OP take the respective modified forms:

$$B_{bf} \sim Q_{bf}^{0.57} Q_{tbf}^{0.43} D^{0.34} \quad \text{(C5a)}$$

$$H_{bf} \sim Q_{bf}^{0.45} Q_{tbf}^{-0.45} D^{-0.38} \quad \text{(C5b)}$$

$$S \sim Q_{bf}^{-0.80} Q_{tbf}^{0.80} D^{0.76} \quad \text{(C5c)}$$

In our analysis of the response of the Fly River, Papua New Guinea to sea level rise, we have replotted Figs 9, 10, 11 and 12 of OP in the respective Figs C2, C3, C4 and C5 of this RD. In the latter figures, lines are shown for the assumption of the constant Shields number, the proposed relation of OP, and the modified relation herein, i.e. RD. The RD results differ only modestly from the OP results, with the largest difference appearing for the case of bankfull width. Our reanalysis also implies a modest change in Fig. 13, but we have omitted this here for brevity.

2. "What the Authors failed to note is the fact that $H_{bf} \sim S^{-N}$, which is supported by the data as shown in Fig. D1." We refer the Discusser to Fig. 3a of OP. Although the regression equation is not shown on the figure, the dashed line does in fact correspond to the least square log-linear regression of $\tilde{H}_{bf}$ versus S; the value of N is 0.514.

3. "A correlation between slope and grain size is clear from the data in Fig. D3, and well supported in classical fluid mechanics." In the first part of OP (up to and including Section 3), we illustrate empirically that when bankfull shear velocity u_{*bf} and bankfull depth H_{bf} are considered as functions of bed slope S and bed material grain size D, the dependence on D can be neglected. We modify this result herein: the dependence on D

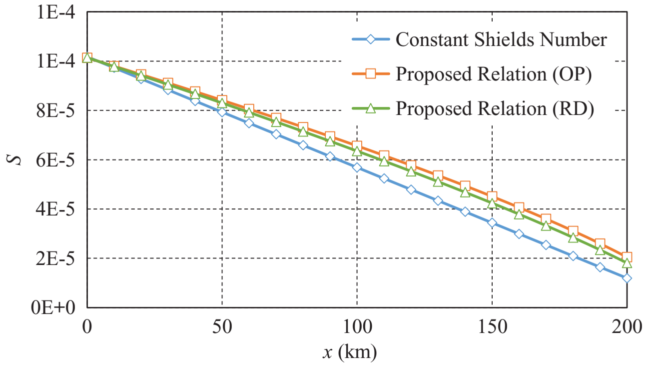

Figure C4 Model predictions for the downstream variation of bed slope for the Fly-Strickland River system under conditions of steady-state response to constant sea level rise. Results are shown for the constant bankfull Shields number model and the proposed variable bankfull Shields number model of the original paper (OP) and the reply to Discussion (RD)

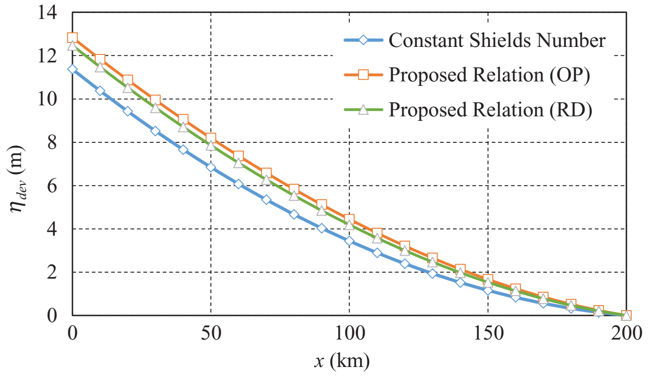

Figure C5 Model predictions for the downstream variation of deviatoric bed elevation for the Fly-Strickland River system under conditions of steady-state response to constant sea level rise. Results are shown for the constant bankfull Shields number model and the proposed variable bankfull Shields number model of the original paper (OP) and the reply to Discussion (RD)

is instead very weak. We do not imply that S is uncorrelated to D. Indeed, Eq. (22c) of OP indicates that $S \sim D^{0.75}$, and we have modified this in Eq. (C4c) to $S \sim D^{0.76}$.

4. There is a typographical error in OP. "The conclusion in Eq. (5) that the exponent of D^* is -1.00 is confirmed by splitting the data into two subsets, one for which $D \leq 25$ mm and one for which $D > 25$ mm. The corresponding exponents of D^* are -0.096 and -1.048, i.e. only a very modest deviation from -1.00." The exponent "-0.096" should have been "-0.96".

5. The Discusser proposes the following equation:

$$u_{*bf}/V = f\left(VD/\nu,\ D/H_{bf},\ shape,\ V^2/(gD)\right) \tag{C6a}$$

The essence of our arguments can be captured by the modification of the above equation to:

$$u_{*bf}/V = f\left(VD/\nu,\ D/H_{bf},\ shape,\ V^2/(gD),\ v_{s,bank}/V\right) \tag{C6b}$$

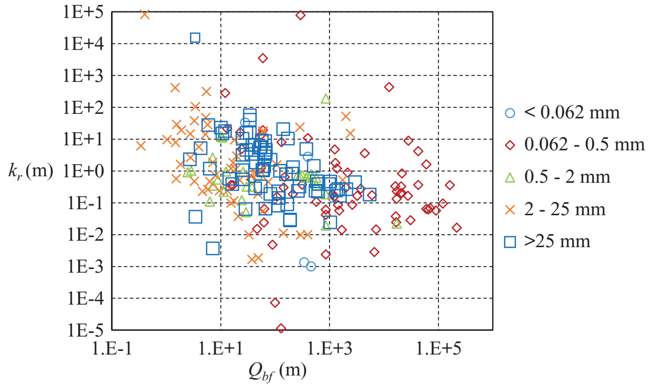

Figure C6 Comparison of bed roughness height as computed from Eqs (6a) and (6b) to the bankfull water discharge; data consist of the full dataset used in this paper and are segmented by grain size to show similar scatter across all grain sizes

where for our analysis, V can be identified as cross-sectionally averaged bankfull velocity U_{bf}. That is, we hypothesize that the fall velocity $v_{s,bank}$ of the material that is emplaced to form the banks exerts an important control on bankfull geometry itself. We cannot prove this because we do not have the relevant data in hand. But the fall velocity of fine-grained material is certain to be dependent on viscosity.

6. "Finally, the Discusser found it troublesome that the Authors believe the Chezy equation is superior to Manning's equation . . . the Discusser . . . observes that the Manning's n is supported by a lengthy history of use and reference values for various engineering surfaces and natural channel types . . . " We quoted Ferguson (2010) in this regard, but we elaborate here. Using the Manning–Strickler form specified in Wong and Parker (2006), Manning's equation can be written as:

$$U = \frac{1}{n} H^{2/3} S^{1/2} \tag{C7a}$$

$$\frac{1}{n} = \alpha_r \frac{\sqrt{g}}{k_r^{1/6}} \tag{C7b}$$

where U, H, S and n denote cross-sectionally averaged flow velocity, depth, slope and Manning's n, respectively, k_r denotes roughness height and α_r is dimensionless coefficient that Wong and Parker (2006) evaluated as 8.1 using data for flow over a hydraulically rough bed in a straight channel, in the absence of any bedforms. In general, H should be replaced by hydraulic radius, but we do not do so here for simplicity. In Fig. C6, we plot k_r as computed from our dataset and Eqs (6a,b) versus bankfull discharge Q_{bf}. The computed values of k_r scatter over at least six orders of magnitude. We suggest that the use of Manning's equation in natural channels is more of a historical convention than a scientifically justified procedure.

7. "The Authors used their relationship to state that the increased vegetation density in their Figs 4 and 5 led to greater shear stress due to increased fines, and therefore by their hypothesis, viscous effects. The Discusser interprets this

observation as additional form drag, or alternatively vegetation density can be interpreted as an increase in the characteristic roughness element height."

We point out that we do not refer to in-channel vegetation, which might change the roughness of in-channel flow. Instead, we refer to bank and floodplain vegetation. The fall velocity of fine-grained floodplain material derived from the upper part of the column of suspended sediment in the river can be expected to be viscosity-dependent. This fine-grained material, once deposited, promotes vegetation, which in turn promotes further deposition of fine sediment. Although the drag on individual stems or trunks of floodplain vegetation undoubtedly plays a role, our key emphasis is on the fine-grained material itself.

References

Wong, M., & Parker, G. J. (2006). Reanalysis and correction of bed-load relation of Meyer-Peter and Müller using their own database. *Journal of Hydraulic Engineering*, *132*, 1159–1168.

http://dx.doi.org/10.1080/00221686.2015.1137088