Laminar morphodynamics: a tribute to Stephen Coleman

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1. Introduction
Features of interest in river morphodynamics include ripples, dunes, antidunes, single-row and multiple-row bars, and channel meandering and braiding. In the field, the flows associated with these features are in the turbulent regime. Perhaps because of this correspondence, it has been argued that turbulence is a necessary condition. It is demonstrated in Lajeunesse et al. (2010a), however, that every one of these features can be reproduced under laminar or nearly-laminar flow.

2. Morphodynamic phenomena in laminar flow
Laminar flow that transports sediment can be achieved in the laboratory by using a) very small-scale flows of water with lightweight sediment, or b) flows at more common laboratory scales using a highly viscous fluid such as oil. Lajeunesse et al. (2010b) determined a bedload transport relation for laminar conditions.
As summarized in Lajeunesse et al. (2010a), the following features have been reproduced at laminar scale: a) self-formed straight channels with mobile beds, b) asymmetric, downstream migrating dunes/ripples c) upstream-migrating antidunes, d) bars, e) braiding, and f) meandering (this under nearly-laminar conditions).

3. The role of turbulence and scaling
Turbulence is indeed not necessary for any of these phenomena. When it is present, it plays an important role. For example, the applicable bed resistance and bedload transport relations are different. In addition, vigorous sediment suspension is absent under laminar conditions. As result, the range of river morphodynamics which can be reproduced at laboratory scale is that associated with bedload transport.
Precise Froude and Shields number scaling cannot be achieved between turbulent to laminar regime. Yet this limitation is not an impediment. The fluid dynamic and morphodynamic framework remain identical for both cases, with only the closure relations differing. It is shown in Lajeunesse et al. (2010a), for example, that secondary flow in bends has a common structure for both laminar and turbulent flows. Devauchelle et al. (2007) have shown that stability formulations for the formation of alternate bars originally developed for turbulent flow are readily adaptable to laminar flows.

3. The role of Stephen Coleman

Stephen Coleman was a greatly admired colleague who died on July 23, 2012 at the age of 46. His doctoral thesis on river sand waves merited him the Lorenz G. Straub Award for Best Thesis in 1995. Coleman pursued a lifelong interest in sediment transport, turbulence structure in rivers and local scour, so distinguishing himself as an outstanding researcher and a decent and caring human being.

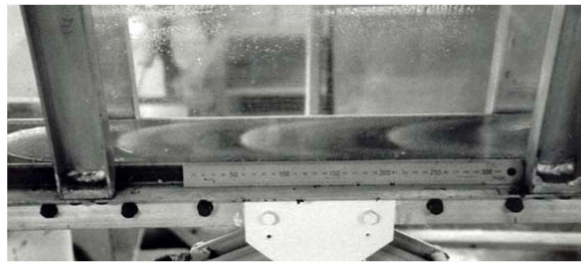

Figure 1: Bedforms produced by Coleman and Eling (2000) under conditions of laminar flow.

At some point in the 1990's, Coleman showed the first author of this abstract some research performed using hydraulic oil flowing over a bed of loose sand. These experiments clearly demonstrated the formation and propagation of dune/ripple structures under laminar conditions (Figure 1). (One of the commonly-used criteria for distinguishing between the two, i.e. the existence or absence of a viscous sublayer, breaks down for laminar flow.) Coleman indicated that he would probably not publish this work, in that few researchers were likely to be interested. The first author of this abstract has the pleasure to report that he insisted that Coleman publish it. This paper was one of several key papers that led to the recognition of the power of analogy between laminar and turbulent morphodynamics.

References
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