Analogy of the Sedimentary Morphodynamics of Turbidity Currents and River Flows

E. Puhl[1]
[1] NECOD/IPH, Univ. Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil. eduardo.puhl@ufrgs.br

1. Introduction

In natural and artificial reservoirs density currents have been identified as important agents of sediment transport. Therefore, the understanding and characterization of this type of flow allows greater predictability of its occurrence and the volumes to be transported. The identification of bed forms are commonly used tools for correlation with the state of the flow. To this end, turbidity currents were simulated in the laboratory at permanent conditions in order to achieve a state of dynamic equilibrium with the moving bed.

2. Methodology

A unidirectional channel (Fig. 1) was used (5.35 m long, 0.30 m wide and 0.38 m high) which sited in a 3° slope. The mixtures were composed of fine kaolin (d_m = 23 μm) and injected into the channel at a constant discharge of 2 litters/sec for 30 min in each experiment. Two experimental series were made by a succession of experiments, i.e. each experiment was subjected to the final state of the previous experiment in the series. The high concentration series (Phase A - C_v = 2.7%) was composed of 3 experiments, a total of 90 min and the low concentration series (Phase B - C_v = 1.25%) was composed of 4 experiments, a total of 120 min. Velocity and sediment concentration measurements were made at a point 3.50 m from the injection point, and a survey of the bed features were done over the experiments.

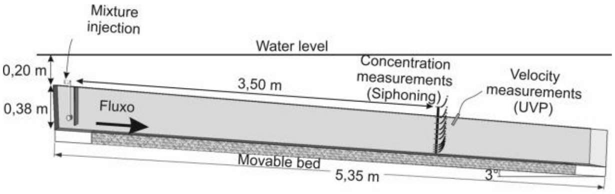

Figure 1: Schematic view (not to scale) of the physical model used and the location of the measurement equipment.

3. Results

From current parameters measuring it was observed (Fig. 2) that the high concentration currents accelerated over time while increasing thickness and dilution. On the other hand, at the low concentration series there was a retraction of the current, i.e. thinning and progress of a well-developed basal layer. Finally, a state of dynamic equilibrium between the flow and the bed could be attested in both series after a flow adjustment period of approx. 60 min. Under these conditions the hydrodynamic parameters of the flows reach stable values: Richardson number (Ri = 0.41 approx.) and coefficient of resistance (c_f = 0.015 approx.). Furthermore, the average bed slope tends to an equilibrium value of 0.07 m/m. In both series, the interaction of the flow with the moving bed generated small wrinkles on flat bed since the early stages of the experiments. Such deformations have evolved (Fig. 3) to straight-crested small ripples followed by undulatory small ripples with amplitudes on the order of 3-9 mm and a wavelength of 70-110 mm.

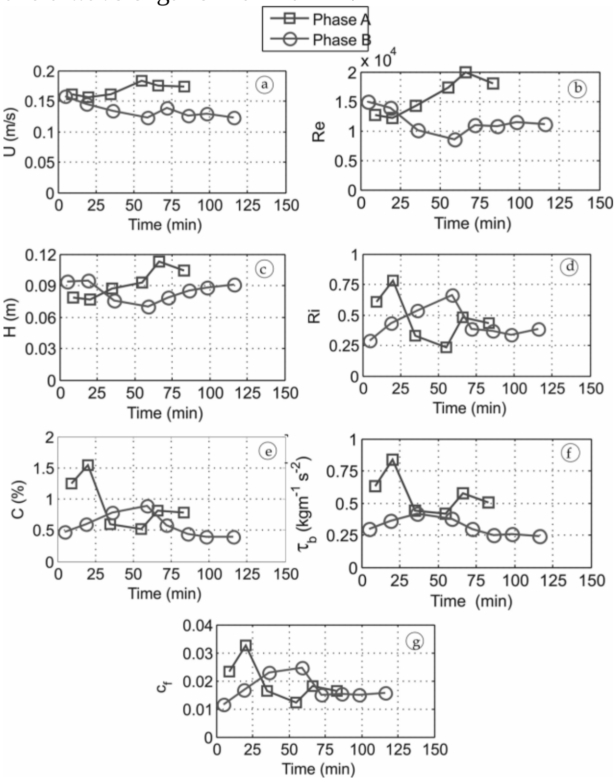

Figure 2: Temporal evolution of the main parameters: (a) mean velocity (b) Reynolds number (c) current height (d) Richardson number (e) suspended sediment concentration (f) bottom shear stress and (g) resistance coefficient.

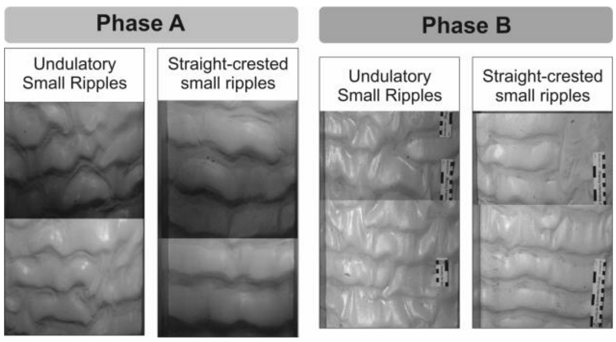

Figure 3: Plan view of the bed forms generated during the experiments, the nomenclature follows classification by Allen (1968).

The bed forms parameters were compared (Fig. 4) with empirical relations of equilibrium condition prediction by Baas (1993) and Raudkivi (1997). From this analysis it is possible to assume that the bed forms were under development since the models over predicted its values, especially for the amplitude. The model proposed by

Baas (1993) has shown good similarity with the length results obtained in the experiments.
Several bed forms phase diagrams built for fluvial bed forms were used to compare the model prediction and the observed results of turbidity currents. However, in most cases the observation and the prediction proposed was not correct, as is the case (Fig. 5) of the Liu (1957) model.

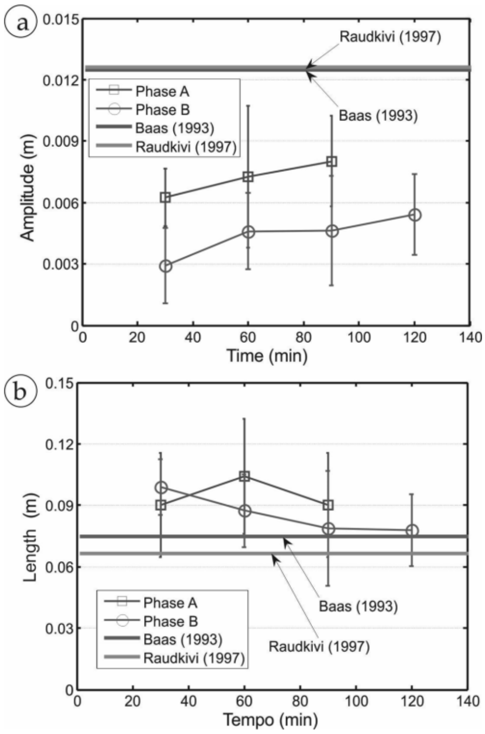

Figure 4: Temporal evolution of amplitude (Δ) and length (λ). The vertical bars represent the standard deviation of the measurements

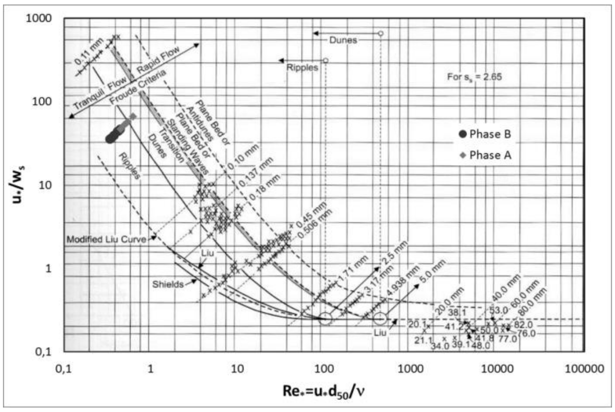

Figure 5: Bed forms phase diagram proposed by Liu (1957) and extended by Simons and Richardson (1961) for bed forms generated by fluvial flows.

4. Discussion and Conclusions

Therefore, mechanisms of generation of the bed forms were observed as similar in many aspects to the bed forms generated by fluvial flows. Accordingly, the use of empirical relations to predict current ripples dimensions has shown good agreement with the wavelength of the experimental bed forms, but the empirical models over predicted its amplitudes. Similarly, comparisons were made with fluvial bed forms phase diagrams of various authors. However, in most cases, was observed discrepancy between the predictions made. Finally, the analysis has shown that parameterization used for turbidity currents is not compatible with that traditionally used for river flow; despite its formation and evolution were very similar.

References

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