Interactions among gravel and sand fractions during transport as measured by impact plates and sedflux monitor in a laboratory channel

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Abstract

Accurate measurements or predictions of bed load transport are difficult to make for alluvial channels especially when the bed material consists of a mixture of sand and gravel. A series of experiments were conducted in a laboratory flume in which gravel and total bed load rates were measured continuously using independent methods. The effect of four different antecedent conditions on the transport of bed load during a standard low flow condition was evaluated in a series of experiments. It was found that different mean rates of bed load transport occurred for the standard low flow following different antecedent flow strengths. This work indicates that a portion of the uncertainty of accurately predicting transport rates for gravel bed streams is likely caused by changes in the surface characteristics of the gravel bed that result from antecedent flows which affect the rate of transport for subsequent other flows.

Introduction

The large temporal and spatial variations that characterize the transport of bed load make it very challenging to measure or estimate accurately. Recent studies have shown that the characteristics of the bed surface layer as well as the grain size information are required to predict rates of bed load transport. The flow history has been shown to be a factor in the type of characteristics that form on the bed of streams with gravel in the bed material (Mao, 2018; Ockelford and Haynes, 2013). Inadequate knowledge of the characteristics of the bed surface layer are among the factors that make it challenging to accurately predict the rate of bed load transport for a given flow strength. In this study the bed load transport was measured using a standardized flow after four antecedent flows had been imposed on a flume channel with a bed consisting of gravel and sand.

Methods

Experiments were conducted in a flume channel 30-m long, 1.2-m wide, and 0.6-m deep with an adjustable longitudinal slope. Seven experiments, in which steady flows were imposed on the channel, were completed in this study. The four standard experiments (1a-1d) had nearly the same flow and the three other experiments (2a-2c) were of greater flows and served along with the initial screeded bed as the antecedent flows in this study (Table 1). The sediment in the flume was a bimodal mixture of sand (modal diameter = 0.5 mm) and gravel (modal diameter =22.6 mm) with a range in sizes from 0.062 to 45 mm. Sediment and water were recirculated and bed load rate was measured at 1 Hz with two recording drum samplers in a trap which spanned the entire width of the channel.

Four experiments had the same flow but were run after different antecedent flows thus yielding unique recent past flow histories in each case. Experiment 1a was conducted after the bed was mixed and screeded flat. The runs were conducted in the order in which they are listed in Table 1. The bed was not remixed or screeded after the experiments began.

Results

The rates of bed load transport for the four standard flow rates are shown in Figure 1. The mean rates of sediment transport and fluctuations about the mean were different for the four experiments. The magnitude of the first peak in the transport of bed load is also different in the four experiments. The ratios of the standard deviation to the mean bed load rate (coefficients of variation) (Table 1) in the experiments were found to be greatest for the first experiment (1a) and to decrease for the next two standard flow experiments until increasing again for the fourth experiment (1d).

Conclusions

The different mean bed load transport rates and coefficients of variation for the four standard experiments (1a – 1d) resulted from the different previous flows to which the channel was subjected. It is likely that these measured differences in bed load transport for equivalent flows resulted from different characteristics of the bed surface layer which formed during the different antecedent flows to which the channel was subjected. The changes in bed surface characteristics caused by the antecedent flows persisted in the standard experiments for at least 45 hours. These findings are consistent with results from a previous study (Mao, 2018).

Table 1. Flow conditions during the experiments

Experiment	Total run time (hr)	Flow discharge (m^3/s)	Mean flow depth (m)	Froude number	Mean bed load transport rate (kg/hr)	Coefficient of variation of bed load
1a	47.2	0.250	0.253	0.51	28.6	0.94
2a	47.0	0.295	0.256	0.60	189.6	
1b	46.5	0.248	0.260	0.49	39.1	0.92
2b	46.4	0.324	0.268	0.61	359.0	
1c	47.6	0.247	0.262	0.48	35.1	0.71
2c	45.2	0.343	0.264	0.66	666.7	
1d	46.7	0.249	0.263	0.48	33.0	0.79

References

Mao, L., 2018. The effects of flood history on sediment transport in gravel-bed rivers. Geomorphology, 322, 196-205.

Ockelford, A. M., Haynes, H., 2013. The impact of stress history on bed structure. Earth Surface Processes and Landforms, 38, 717-727.

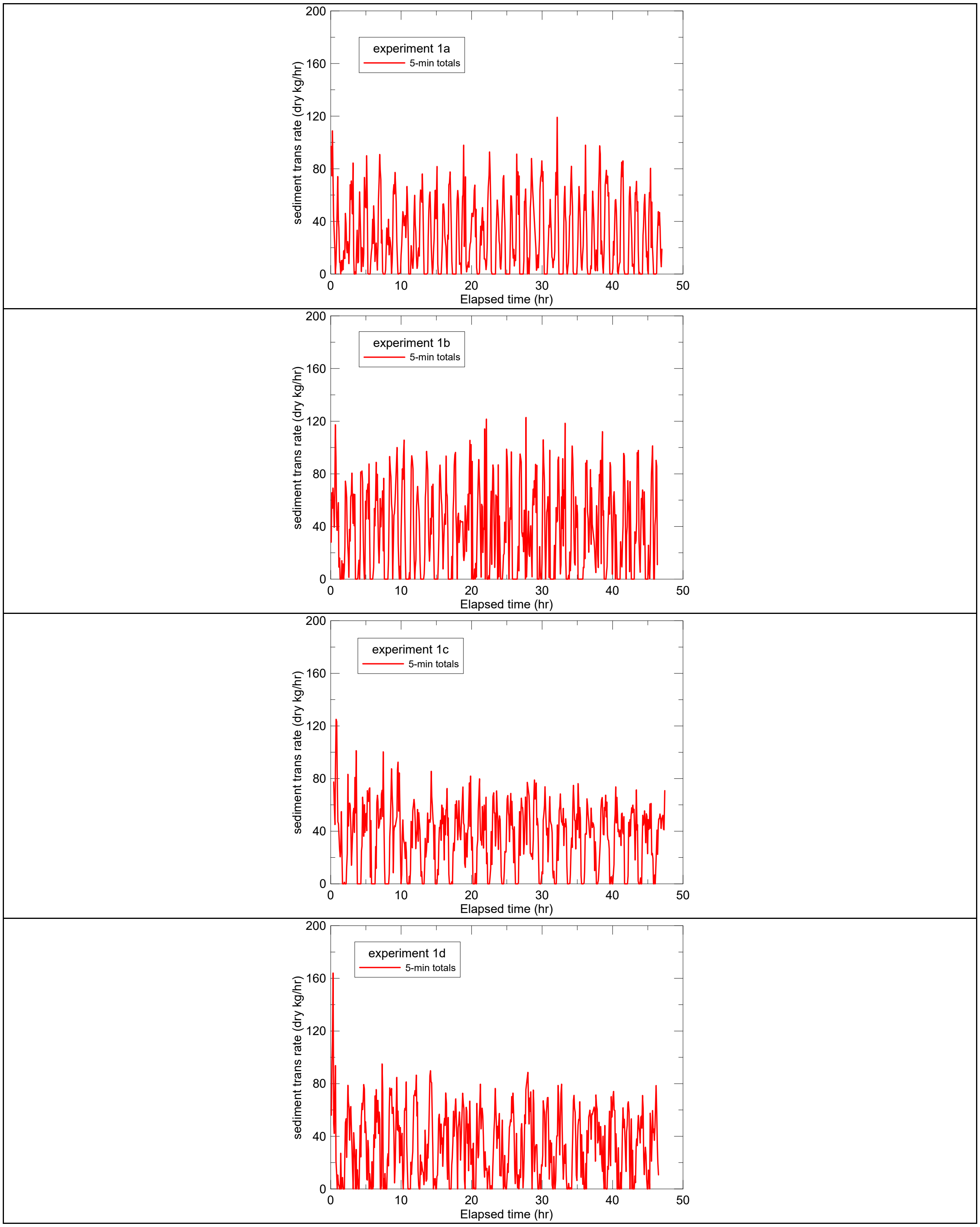

Figure 1. Bed load transport versus time for the four experiments with standard flows in this study.