Bed form evolution under unsteady discharge, flume versus field

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Introduction

Accurate forecasts of flood levels are essential for flood management. During floods, bed forms develop on the river bed. Dunes have heights in the order of 10–30% of the water depth and lengths in the order of 10 times their height. River bed forms act as roughness to the flow, thereby significantly influencing the (flood) water levels. It is essential to predict the time evolution of bed forms and assess their influence on the hydraulic roughness.

Field observations have shown that dunes of different lengths and amplitude co-exist (Carling et al., 2000; Wilbers & Ten Brinke, 2003; Frings & Kleinhans, 2008). Secondary bed forms and their interaction with primary bed forms are not recorded in most flume data sets. This raises the question if there is a difference in bed form evolution between flume and field. Therefore, the objective of this paper is to assess the differences in bed form evolution under unsteady discharge between flume and field and explain the interaction between primary and secondary bed forms.

Observations from data

We used the flume data from Wijbenga and Van Nes (1986) who imposed two gradually varying discharge waves in the flume at Delft Hydraulics one with a duration of 3.5h (T43) and one with a duration of 7h (T44). We used the field data from Wilbers and Ten Brinke (2003) and Julien et al. (2002) of two discharge waves of 1995 and 1998 in the river Rhine and Waal.

Figures 1a and 1c show the dune height and dune length evolution in the flume during the T43 and T44 discharge waves. Figures 1b and 1d show the dune height and dune length evolution during the three discharge waves in the river Rhine.

The dune height in figure 1 follows a steep slope during the rising limb of the discharge wave and a more gentle slope during the receding limb. This trend is also shown for the field data and is logical, because dune height adapts faster to the flow during increasing discharge as the flow is stronger and the dune height is small and slower during falling discharge due to the inverse effect.

In the flume data was visible that the

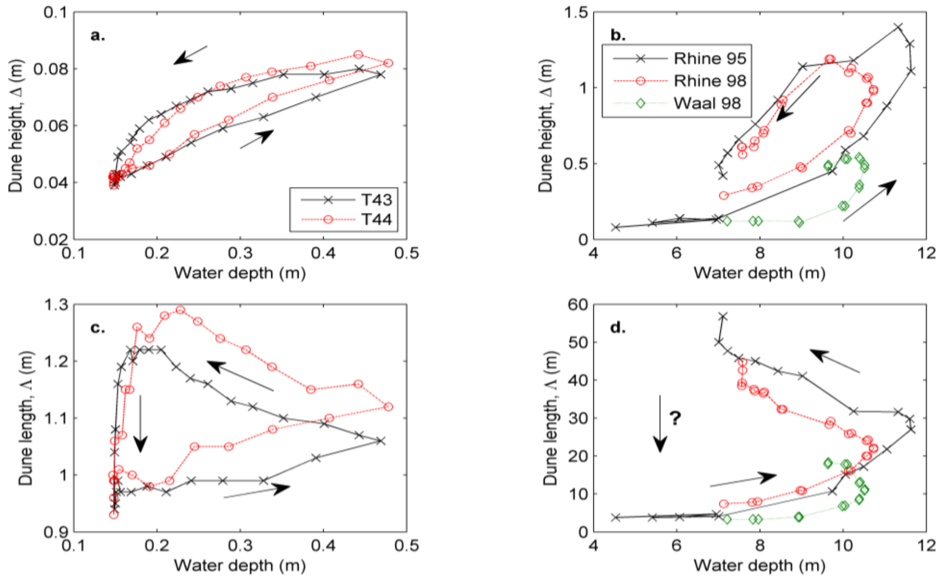

***Figure 1** Hysteresis curves of dune height for (a) flume data, (b) field data and of dune length for (c) flume and (d) field data*

decrease in dune length is equal or faster than the increase. This is not expected, because the adaptation time of dune length is larger than of dune height, so dune length was expected to decrease even slower than dune height. In the field data, a decrease of dune length is not observed (see question mark in figure 1d). The dune lengths seem to infinitely increase until the point where these large dunes are no longer observed in the data.

In conclusion, the dune height evolution is similar in the flume and in the field, but the decrease of dune length that is observed in the flume is not visible in the field measurements, where dune length only seems to grow. Furthermore, secondary dunes are not identified in the flume data, but are only present in the field data.

New hypothesis for dune length evolution

To explain the observed decrease in bed form length in the flume and field data, we propose an hypothesis based on super-imposition of secondary bed forms. Figure 2 illustrates this hypothesis. The key is that dune length of an individual dune never decreases, but only increases and that secondary bed forms are responsible for the observed decrease in bed form length, because they develop on top, and during decreasing discharge, they become dominant. Because these secondary dunes have a smaller length, the dune length rapidly decreases.

In essence: during decreasing discharge, the primary dunes decrease in height, but increase in length, resulting in low angle dunes and later in flat bed. Simultaneously, secondary dunes develop on top and become the new primary dunes.

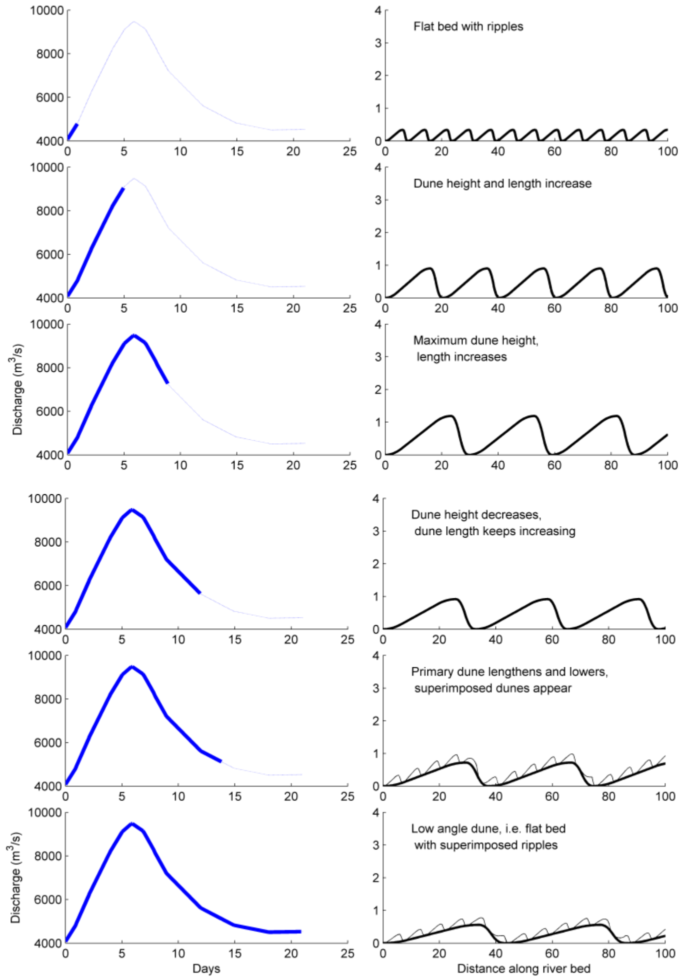

Figure 2 *Proposed model of bed form evolution under varying discharge in flume and field. Left plots: discharge wave of 1995. The right plots illustrate dune development, based on dune height and lengths as observed in the Rhine in 1995 (data from Wilbers and Ten Brinke 2003)*

Further research will focus on validation of the proposed hypothesis and including this process in existing computer models for flood forecasting. More details of this research can be found at Warmink et al. (2012)

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