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Adapting the Coleman et al. (2005) time-lag approach for application under unsteady discharge

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ABSTRACT: The Coleman et al. (2005) time-lag approach for prediction of bed form dimensions in rivers was originally developed for steady discharge. In this study, the time-lag approach was adapted for application under discharge waves. The application on a discharge wave in a flume experiment shows that including the time-lag approach, enhances the amount of hysteresis between discharge and roughness and may improve the prediction of peak water levels in an operational water level prediction model.

1. INTRODUCTION

River dunes are the dominant bed forms in many rivers. The height is in the order of 10 - 30% of the water depth and their length in the order of 10 times their heights. Under flood conditions the bed is highly dynamic; dunes grow and decay as a result of the changing flow conditions. River bed forms act as roughness to the flow, thereby significantly influencing the water levels. Accurate and fast computer models are required to predict daily water level forecasts for operational flood management and forecasting. It is essential to predict the time evolution of bed forms and assess their influence on the hydraulic roughness.

Coleman et al. (2005) used an analytical time-lag approach to predict dune evolution in a flume experiment with discharge steps. They showed that their approach provides reliable predictions of dune dimensions under step varying discharge. The objective of this study was to extent the Coleman et al. (2005) approach for a discharge wave experiment in a flume. Following Paarlberg & Schielen (2012), we couple this dune evolution model to a 1-D Sobek model to predict the water levels during a discharge wave in a flume (results not presented in this abstract). We used data from two flume experiments of a discharge wave of Wijbenga & Van Nes (1986): experiment T43 with a duration of 3.5 h and experiment T44 with a duration of 7 h (Twave = 3.5 and 7 h, respectively), see figures 1 and 2.

2. METHOD

Coleman et al. (2005) adopted the commons scaling relationship for sand-wave development from an initially flat bed from Nikora & Hicks (1997):

$$\frac{P}{P_e} = \left(\frac{t}{t_e}\right)^{\gamma} \quad \text{for } 0.01 < \frac{t}{t_e} < 1 \qquad [1]$$

where P is the average value of dune length or height, P_e is the equilibrium value, t is time, t_e is the time to achive P_e, and γ is a growth rate parameter. Coleman et al. (2005) derived a relation for γ, based on many flume experiment with a discharge step. They showed that growth rate was different for dune height, γ_H, and dune length, γ_L, and only depended on sediment size, D:

$$\gamma_H = 0.22 D_*^{0.22} \approx 0.37 \qquad [2]$$

$$\gamma_L = 0.14 D_*^{0.33} \approx 0.32 \qquad [3]$$

Furthermore, the Coleman approach requires an estimate of the time-to-equilibrium, t_e, and the equilibrium dune dimensions. In this study H_{eq} =

0.3h and $L_{eq} = 2\pi h$ were chosen following Yalin (1992).

Coleman et al. (2005) derived an equation to predict t_e, based on shear velocity, u_*, water depth, h, the Shields number, θ, and critical Shields number, θ_{cr}:

$$t_e\left[\frac{u_*}{D_{50}}\right] = 2.05 * 10^{-2}\left[\left(\frac{D_{50}}{h}\right)^{-3.5}\right]\left[\left(\frac{\theta}{\theta_{cr}}\right)^{-1.12}\right] \quad [4]$$

Note that this equation is highly empirical and shows a large scatter.

The Coleman approach is not directly applicable for discharge waves, because the equilibrium water depth is unknown in case of unsteady discharge. Therefore, the time step to compute the equilibrium state affects the growth rate (due to non-unity of the γ, which describes the adaptation speed).

In the new approach the growth rate is assumed to be independent of γ and instead included in the prediction of t_e, thereby assuming linear growth from the dune dimension at t_0 to the dimension at t_e. This assumption has a negligible effect if the time step is much smaller than the duration of the discharge wave. Additionally, the time to equilibrium, t_e, was adapted to correct the growth rate. A separate te value was adopted for dune height and dune length, which is feasible because dune height adapts faster to the flow than dune length.

3. RESULTS

Figures 1 and 2 show the predicted dune dimensions using time-lag, which are now independent of the chosen interval to determine equilibrium conditions (for dt << Twave) and bed form dimensions are predicted well. Using Van Rijn (1993) to transform dune dimensions to roughness, Figure 3 illustrates that the Coleman predicted hysteresis is more pronounced than the hysteresis using the water depth based equilibrium predictors.

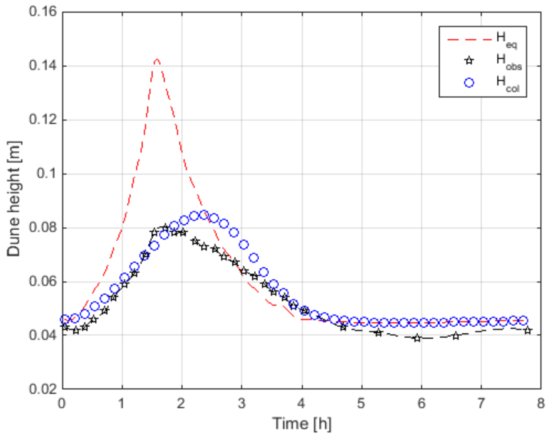

Figure 1. Dune height. The pentagrams represent the observations from experiments from Wijbenga & Van Nes (1986), the dashed lines show the equilibrium predictions using Yalin (1992) and the open circles show the Coleman predicted dune heights.

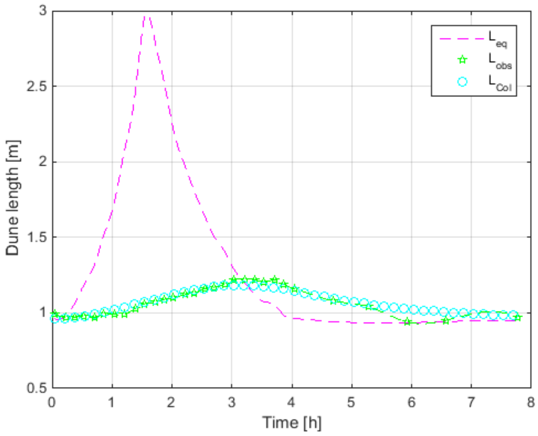

Figure 2. Dune length. The pentagrams represent the observations from experiments from Wijbenga & Van Nes (1986), the dashed lines show the equilibrium predictions using Yalin (1992) and the open circles show the Coleman predicted dune lengths.

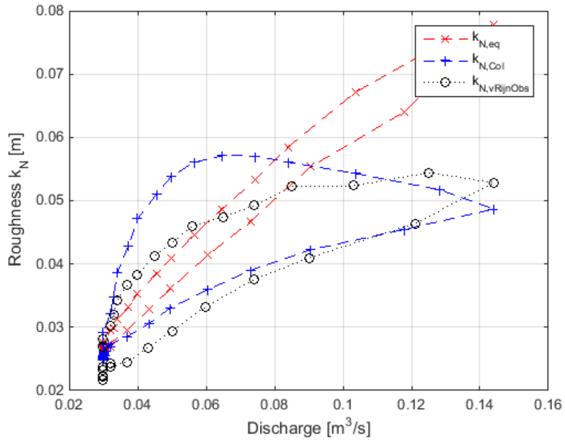

Figure 3. Hysteresis curves between discharge and roughness (k_N), based on dune dimensions from equilibrium predictors (x), adapted Coleman (+) and observed dune dimensions (o).

4. CONCLUSIONS

The Coleman et al. (2005) time-lag bed form model was successfully adapted for application on gradually varying discharge waves. This approach is applicable for the prediction of hysteresis due to bed form roughness the prediction of water levels. The advantages of the time-lag approach compared to more detailed physically based modelling strategies is that it is fast and captures the essential process to predict hysteresis. The results show that replacing the main channel roughness by the time-lag predicted roughness may improve the prediction of water levels.

The time-lag approach proved highly sensitive for the prediction of the equilibrium bed form dimensions. For reliably using this method in the field, future work is required to improve the equilibrium bed form predictors for field situations. The presented approach is limited to lower regime bed forms and not valid for transitions to upper stage flow regimes. Extending the approach, by including transitions to other regimes in the equilibrium predictor needs further study.

5. ACKNOWLEDGMENT

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6. REFERENCES

Coleman S.E., Zhang M.H., Clunie T.M. 2005. Sediment-wave development in subcritical water flow Journal of Hydraulic Engineering, 131, 106-111, doi: 10.1061/(ASCE)0733-9429(2005)131:2(106).

Paarlberg A.J., Schielen R.M.J. 2012. Integration of a dune roughness model with a large-scale flow model. In: Murillo (Ed.) Proc. of River Flow 2012, Costa Rica, pp. 155-161.

Van Rijn L.C. 1993. Principles of sediment transport in rivers, estuaries and coastal areas. Aqua Publications, The Netherlands.

Wijbenga J.H.A. & Van Nes A.R. 1986. Flow resistance and bedform dimensions for varying flow conditions; results of flume experiments with flood waves. WL|Delft Hydraulics research report. R657, M1314 Part XIII.

Yalin M.S. 1964. Geometrical properties of sand waves. Journal of the Hydraulics Division, HY5, 105-119.