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Assessment of the Accuracy of Numerical Morphological Models based on Reduced Saint-Venant Equations

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Sustainable river management often requires long-term morphological simulations. As the future is unknown, uncertainty needs to be accounted for, which may require probabilistic simulations covering a large parameter domain. Even for one-dimensional models, simulation times can be long. One of the acceleration strategies is simplification of models by neglecting terms in the governing hydrodynamic equations. Examples are the quasi-steady model and the diffusive wave model, both widely used by scientists and practitioners. We established under which conditions these simplified models are accurate.

Based on results of linear stability analyses of the St. Venant-Exner equations, we assessed migration celerities and damping of infinitesimal, but long riverbed perturbations. We did this for the full dynamic model, i.e. no terms neglected, as well as for the simplified models. The accuracy of the simplified models was obtained from comparison between the characteristics of the riverbed perturbations for simplified models and the full dynamic model.

We executed a spatial-mode and a temporal-mode linear analysis and compared the results with numerical modelling results for the full dynamic and simplified models, for very small and large bed waves. The numerical results match best with the temporal-mode linear analysis. We show that the quasi-steady model is highly accurate for Froude numbers up to 0.7, probably even for long river reaches with large flood wave damping. Although the diffusive wave model accurately predicts flood wave migration and damping, key morphological metrics deviate more than 5% (10%) from the full dynamic model when Froude numbers exceed 0.2 (0.3).