Determining morphological stability of tidally-influenced bifurcations

Arya P. Iwantoro¹, Maarten van der Vegt¹ and Maarten Kleinhans¹
¹ Department of Physical Geography, Utrecht University, Utrecht, the Netherlands. Presenting author: a.p.iwantoro@uu.nl

Introduction

The morphology of river bifurcations often evolves asymmetrically, resulting in an avulsion (unstable bifurcation). Observations suggest that bifurcations in tidally influenced systems are stable; however, the stability theory has not been applied to tidal systems. This is because of the presence of bi-directional flows induced by tides, suspended load dominated condition, and typical low channel slopes in tidal deltas and estuaries.

Objective

We aim to study the morphological stability of bifurcations in the range from river- to tide-dominated systems.

Methods

Develop 1D numerical model that solves
- the 1D shallow water equations: mass and momentum balance
- sediment transport: van Rijn 1984
- Sediment division: Bolla Pittaluga et al. (2015)
- Morphological update: Exner equation

Perturb symmetric bifurcation by deepening one of the branches

Does asymmetry grow?

\[
\text{depth ratio} = \frac{h_1 - h_2}{h_1 + h_2}
\]

Results

Why?

We analyse the case with small tides and observe a condition that is unstable for \( \frac{U_{\text{tide}}}{U_{\text{mean}}} = 0 \) but stable for \( \frac{U_{\text{tide}}}{U_{\text{mean}}} = 0.5 \). The instantaneous Shields stress and width-to-depth ratio in one tidal cycle are observed and overlaid in river-only diagram. The growth of asymmetry changes in one tidal cycle and determines the tide-averaged growth.

Conclusion

- Tides can counteract the avulsion process that would occur in river-dominated deltas.
- Increasing tidal range drives a stable bifurcation for larger range of Shields numbers and width/depth ratios.

Reference


River discharge

Tides

No tide

Increased tidal range

Shields stress

water flow

Sediment transport

Tides

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