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Tidal response to polder construction in the Pussur-Sibsa estuary

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Introduction

Intertidal areas impose a strong control on the hydrodynamics in estuaries and tidal inlets. Widespread reclamation of the intertidal zone in the Pussur-Sibsa estuary (PSE), Bangladesh, led to substantial tidal amplification (*Pethick and Orford*, 2013; *Van Maren et al.*, 2022) and radically shifted discharge patterns throughout the estuary. In some places, severe bank erosion followed, whilst in other areas shipping is disrupted due to rapid shoaling. The exact mechanisms behind the observed changes in the PSE are still unclear. In this contribution, we employ an idealized process-based model to investigate the effects of widespread land reclamation on hydromorphodynamics of the PSE.

Field Site

The Pussur-Sibsa estuary (PSE) is a multi-channel subsystem of the larger Ganges-Brahmaputra-Meghna Delta and connects to the Ganges River through the Gorai River. The Sibsa River (western branch) and the Pussur River (eastern branch) join approximately 30 km from the seaward boundary. Prior to their definitive confluence, the Sibsa and the Pussur are connected through four transverse rivers. The Pussur river receives most of its fresh water from the Gorai River, which draws 10-20% of the Ganges discharge. The Sibsa river, on the other hand, only receives fresh water from local precipitation. In the 1960's and 70's, a significant portion of the intertidal planform and peripheral rivers were embanked. Prior to the embankment construction, all discharge from the Gorai found its way to the ocean through the Pussur branch (*NEDECO*, 1967). Half a century later, a substantial part of this fresh water flow is diverted to the Sibsa branch through the connecting channels (*Bain et al.*, 2019). It seems that the gross tidal prism of the Sibsa has significantly increased.

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Methodology

An idealized numerical model resembling the mainstem Sibsa river was constructed to investigate the hydrodynamic changes following a loss of intertidal area along an elongated tidal channel. First, the hydrodynamics of a near-equilibrium tidal channel with extensive intertidal storage is investigated (Figure 1). Next, the response to a series of interventions is explored. Model simulations were carried out using the depth-averaged version (2DH) of Delft3D-flow, and all input files were prepared using MATLAB.

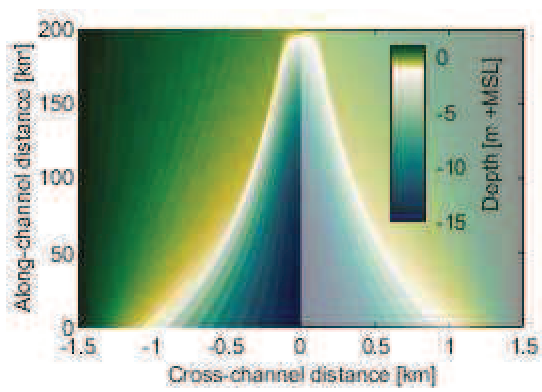

Figure 1: Bathymetry of the idealized numerical model. The lighter shades on the right-hand side denote the area where the flow is not computed directly, but is instead derived by mirroring the results from left-hand side.

The location and extent of embankment construction can vary substantially. Hence, we started simulations with different sections of the intertidal area removed from the model domain. In Bangladesh, land reclamation started inland and shifted progressively towards the coastline. In the PSE, embankment construction stopped 60 to 80 km from the coastline, to preserve the Sundarbans mangrove area. In many other estuaries (e.g. the Western Scheldt in The Netherlands), land reclamation development followed an opposite pattern. It started at the coastline and gradually moved landward. Both cases were included in the simulations, but only the former is shown in this abstract.

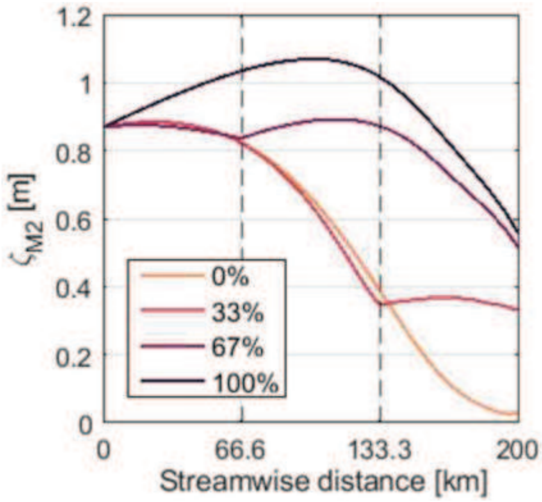

Figure 2: Along-channel profiles of the amplitude of the M2-constituent for simulations with varying degrees of embankment of the intertidal area. Embankment construction starts at the seaward boundary.

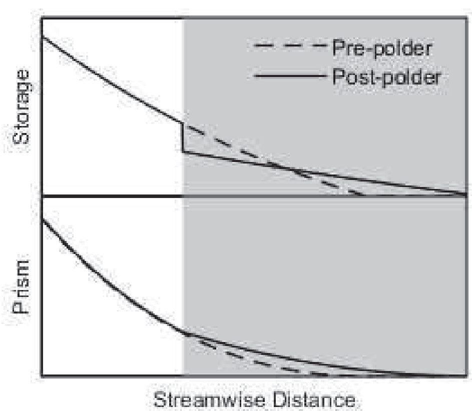

Figure 3: Conceptual profiles of the intertidal storage volume and tidal prism before and after partial embankment of the intertidal area. The grey area denotes the embanked section.

Results

When sections of the intertidal area are removed from the model domain, the tidal amplitude increases within and landward of these sections (Figure 2). Embankment of intertidal area causes a large portion of intertidal storage to be lost. However, the tidal amplification that follows enlarges the intertidal storage within the channel. This increase in intertidal storage is composed of two components: a local increase of the tidal range and stronger landward intrusion of the tidal wave. Consequently, the loss of storage area within the intertidal zone, following its embankment, is more or less completely compensated for by an increase of storage within the channel (figure 3)

Removal of the intertidal area enhances wave propagation in the channel. At the start (or end) of an embanked section, the wave celerity can suddenly increase (or decrease) up to 6 m/s. Especially the removal of the intertidal area near the shallow landward end of the channel, significantly reduces travel times from the inlet to the landward boundary. Embankment of the most landward 33% of the intertidal area reduces the total travel time with 4 hours and 20 minutes.

Discussion and Conclusion

The response of a tidal system to reclamation of its intertidal area can be complex and counter-intuitive. Because the morphological response of the channel seaward of a reclamation is slow, the loss of intertidal storage on the intertidal platform can be compensated for through tidal amplification, and a landward expansion of the tidal influence. As the compensated intertidal storage is situated landward of the lost storage, the tidal prism within and landward of the embanked sections increases, ultimately resulting in channel erosion. Drastic increases of the tidal wave celerity following embankment of the intertidal area may bring the tidal wave closer to or further from resonance conditions. Earlier polder construction in the Sibsa basin resulted in a shift of the intertidal storage into the Pussur, hereby allowing the Sibsa to capture discharge from the Gorai. This study highlights the unexpected changes to water levels and tidal discharges that may proceed from land reclamation, decades after the reclaiming activity took place.

References

Bain, R. L., Hale, R. P., & Goodbred, S. L. (2019). *Flow Reorganization in an Anthropogenically Modified Tidal Channel Network: An Example From the Southwestern Ganges-Brahmaputra-Meghna Delta*. Journal of Geophysical Research: Earth Surface, 124(8), 2141-2159.

Van Maren, D.S., Beemster, J.G.W., Wang, Z.B., Khan, Z.H., Schrijvershof, R. & Hoitink, A.J.F (2022). *Tidal amplification and river capture in response to asynchronous land reclamation in the Ganges-Brahmaputra delta*. Manuscript in preparation.

Netherlands Engineering Consultants - NEDECO. (1967). *East pakistan inland water transport authority: surveys of inland waterways and ports 1963-1967 (Vol. 3, hydrology and morphology.)*

Pethick, J., & Orford, J. D. (2013). *Rapid rise in effective sea-level in southwest Bangladesh: its causes and contemporary rates. Global and Planetary Change*, 111, 237-245.