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DOI
10.5194/egusphere-egu24-9168

Publication date
2024

Document Version
Final published version

Citation (APA)
Schrijvershof , R., van Maren, B., van der Wegen, M., & Hoitink, T. (2024). *Land Reclamation Controls on Estuarine Morphological Evolution*. Abstract from EGU General Assembly 2024, Vienna, Austria. https://doi.org/10.5194/egusphere-egu24-9168

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.

EGU24-9168, updated on 07 May 2024
https://doi.org/10.5194/egusphere-egu24-9168
EGU General Assembly 2024

Land Reclamation Controls on Estuarine Morphological Evolution

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The morphological configuration of estuaries and tidal basins influences future development because the channel-flat pattern and geometry control tidal dynamics and, as a result, residual sediment transport patterns. Large-scale human alteration of estuarine plan-form and channel dimensions, as a result of land reclamation, influences long-term evolution, because the existing balance of sediment import versus export is disrupted. The morphodynamic response to land reclamation is, however, slow, impacting the system for decades to centuries. Consequently, there are usually multiple human interventions cumulatively impacting the system. Our understanding of the cumulative effects of land reclamation and other anthropogenic interference is limited because observations usually do not span the complete morphological adaptation time. The Ems estuary (bordering The Netherlands and Germany) provides an unique site to study the effects of the cumulative impact of land reclamations and 20th-century human interference. Extensive storm surge-formed basins have been gradually reclaimed over a period of 500 years in this well-documented estuary, and dredging works dominated in the past century. Our objective is to quantify the effects of land reclamations and channel dredging on the historic evolution of the Ems estuary from century-scale observations combined with numerical morphodynamic modelling.

We compiled a digitized bathymetric dataset, spanning nearly the full reclamation period, from historical maps, nautical charts, and recent sounding observations. The dataset was used to reconstruct the morphological evolution of the estuary over the past 500 years. The centennial-scale morphodynamic trends show that the system responded to land reclamation by subtidal infilling and evolved from a multichannel system separated by shoals to a single channel system flanked by fringing flats. The long-term geometric changes show that the main system-scale morphodynamic adaptation is controlled by the effects of land reclamation. The present-day evolution is additionally influenced by the effects of 20th-century dredging works.

A process-based morphodynamic model (Delft3D-FM), forced with a synthetic spring-neap tidal cycle, was used to investigate the Ems estuary channel evolution in response to historical land reclamations. Simulation results showcase the transformation from an initially flat-bed bathymetry to a system with multiple channels and tidal flats when historic storm surge basins provide

extensive intertidal areas. Simulations in which these former storm surge basins are reclaimed result in a single-channel system, confirming the influence of land reclamations on the observed evolution. The results of this study emphasize that, contrary to what is generally assumed, pre-dredging estuarine morphologies are often far from pristine. Ongoing research focuses on quantifying the interplay between natural and human-driven factors in century-scale channel evolution.