The influence of recent change in river discharge and bathymetry on tidal wave propagation in the Modaomen estuary, China

Huayang Cai[a,b], Hubert H.G. Savenije[a], Qingshu Yang[b], Suying Ou[b], Yaping Lei[b]

Introduction

Dredging and flow diversion in the Modaomen estuary of the Pearl River in China have had a measurable impact on tidal propagation and damping.

Objective

To assess the impacts of these human interventions on tidal wave propagation:

- Influence of river discharge
- Influence of dredging

Method

Analytical model for tidal wave propagation

Phase lag equation	$\tan(\varepsilon)=\frac{\lambda}{\gamma-\delta}$
Scaling equation	$\mu=\frac{\sin(\varepsilon)}{\lambda}=\frac{\cos(\varepsilon)}{\gamma-\delta}$
Damping equation taking account of river discharge	For zone I, where $\varphi<1$, $\delta=\frac{\mu^2}{\mu^2(\theta-\varphi\zeta)+1}\left[\theta\gamma-\chi\mu^2\lambda^2\left(1+2.66\varphi\zeta+\varphi^2\right)\right]$ For zone II, where $\varphi>1$, $\delta=\frac{\mu^2}{\mu^2(\theta-\varphi\zeta)+1}\left[\theta\gamma-\chi\mu^2\lambda^2\left(1.33\zeta+2\varphi+1.33\varphi\zeta\right)\right]$ $\theta=1-\varphi\left(\sqrt{1+\zeta}-1\right)$
Celerity equation	$\lambda^2=1-\delta\frac{\cos(\varepsilon)}{\mu}=1-\delta(\gamma-\delta)$

Table 1: Explicit equations used for tidal wave propagation

Notation:

ε = phase lag γ = estuary shape number
χ = friction number μ = velocity number
λ = celerity number δ = damping number
ζ = tidal amplitude-to-depth ratio
φ = river discharge-to-river discharge at high water slack ratio

Results

① Sensitivity to river discharge

Both the tidal damping and the travel time of tidal wave increase with river discharge, especially in the upper reach of the estuary.

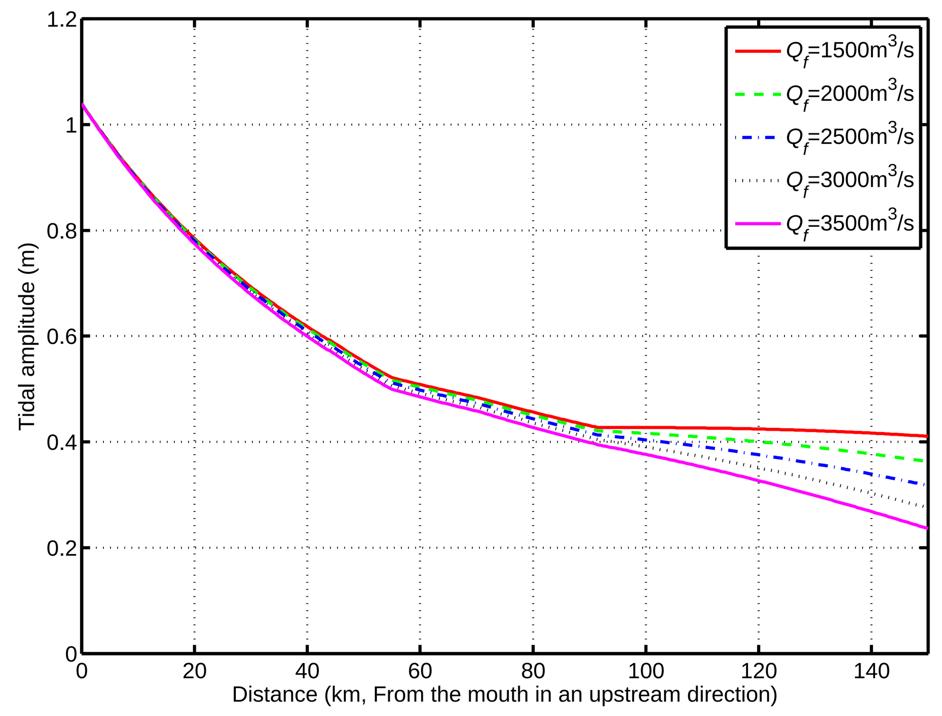

Fig. 1. The longitudinal variation of tidal amplitude under different river discharge conditions

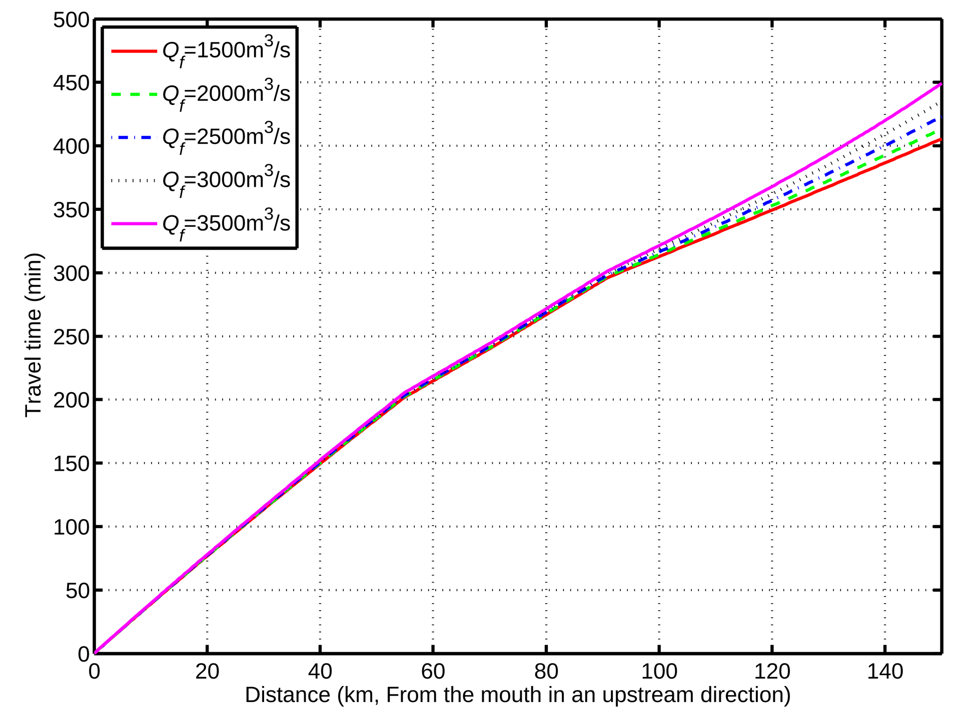

Fig. 2. Propagation of the tidal wave at mean tide under different river discharge conditions

② Sensitivity to dredging

Both the tidal damping and the travel time of tidal wave decrease with a degradation of the riverbed and the more so further upstream.

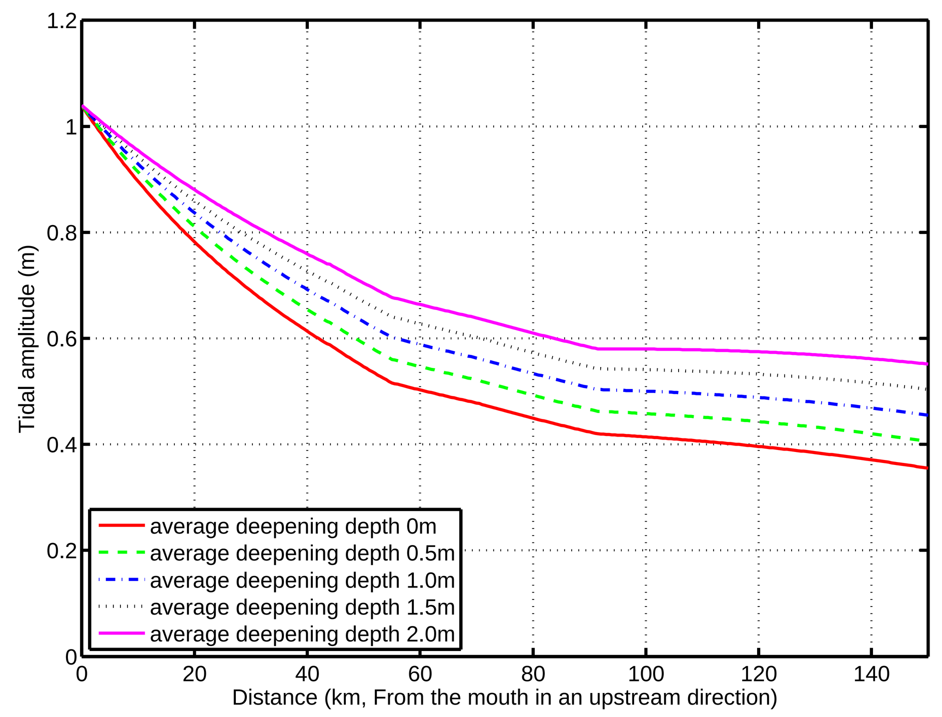

Fig. 3. The longitudinal variation of tidal amplitude under different degradation of riverbed conditions

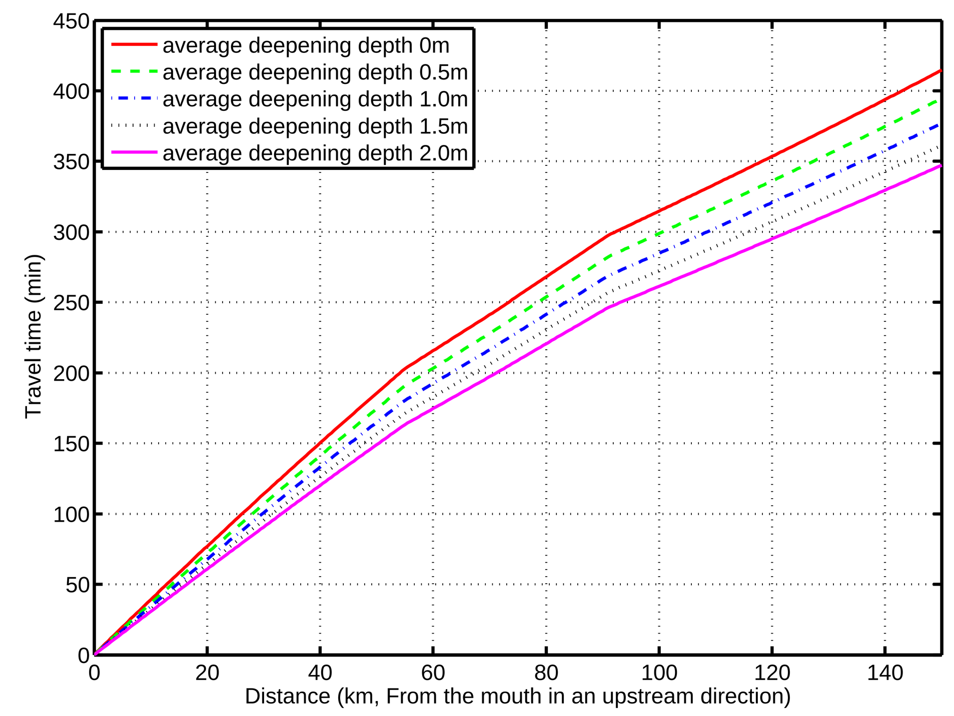

Fig. 4. Propagation of the tidal wave at mean tide under different degradation of riverbed conditions

Results

③ Historic analysis

Due to dredging and flow reduction, since 1993, the tidal amplitude in the Modaomen estuary increased by more than 0.1 m, while the travel time of the tidal wave decreased 20 min in the middle part of the estuary and up to 60 min in the upper reaches.

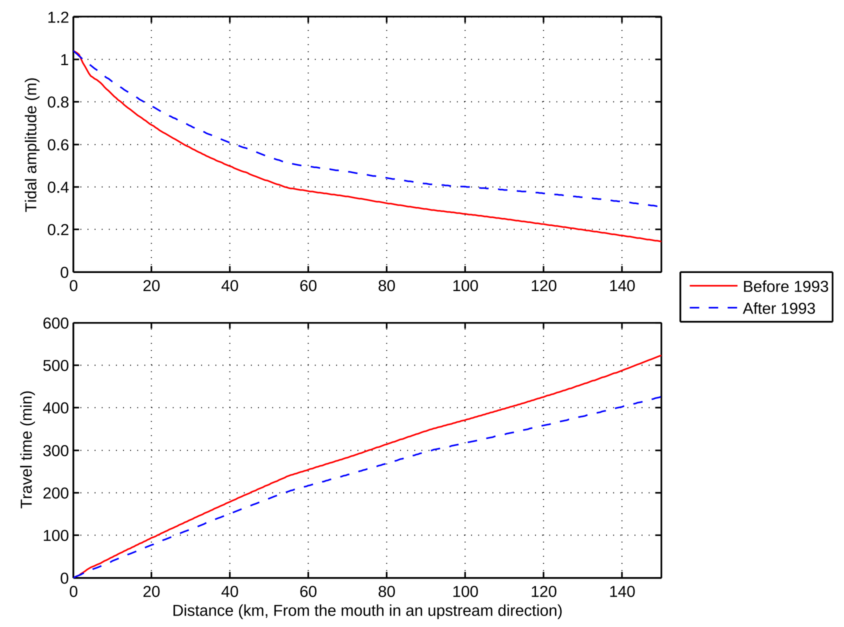

Fig. 5. Influence of river discharge and dredging on tidal wave propagation in the Modaomen estuary

Conclusions

- Dredging and flow reduction both lead to an increase of the tidal amplitude along the estuary axis and that the travel time of the tidal wave is reduced.
- The Modaomen estuary may experience increased risk of salt intrusion and flooding from storm surges as a result of the continuing decrease of river discharge and sand excavation.

[a]Department of Water Management, Delft University of Technology, the Netherlands
[b]Institute of Estuarine and Coastal Research, Sun Yat-sen University, China

Contact: H.Cai@tudelft.nl